THE USE OF MICROBES IN THE DE-WATERING OF FUEL GRADE PEAT

Part 1

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Submitted in partial fulfillment of the requirements of the National Research Council of Canada as specified by the Department of Supplies and Services

DSS File Number 24SU. 31926-3-0070
DSS Contract Number ISU83-00030

Duration June 1, 1983 - May 31, 1984

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c. 1984

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Executive Summary

This research has demonstrated that several types of biological compounds, including polymers, surfactants and enzymes, can significantly enhance the mechanical de-watering of fuel-grade peat. The most promising compounds tested were chitosan and surfactin. Chitosan is a polysaccharide which contains amino-sugars. When these amines are quaternized, the polymer becomes a polyelectrolyte with positive charges along the chain. Surfactin is a surfactant synthesized by Bacillus subtilis which causes extreme lowering of the surface tension of water, to 27mN/m. It also allows spreading of an aqueous solution on waxes extracted from peat. The most difficult peat to de-water encountered in our study was that obtained from Barrington, N.S. This is a highly decomposed peat (von Post of H9). Treating this peat with the biological de-watering agents before pressing, increased the amount of water removed by up to 60%.

A preliminary study revealed that combining heating pretreatment and biological additions caused substantially better de-watering than either process alone. If the Barrington peat was heated at 125°C for 20 min. before pressing, the amount of water removed was increased by about 60%. If the biological agents were added to the peat between heating and pressing the water released was increased by 100%, achieving a moisture content of 61% compared to 78-80% for the controls.

The water expressed from the various peat samples with the use of various additives and treatment procedures contained dissolved and suspended carbonaceous solids. With the addition of small

amounts of other nutrients to these water samples it was possible to grow many different bacteria and yeasts. Using the BOD causing materials, expressed from the peat, as the carbon source for these microorganisms it was possible to produce significant yields of biopolymers and biosurfactants. In particular, it was possible to produce the de-watering agents chitosan and surfactin.

This research has demonstrated the technical feasibility of a "self-contained" process. Biological materials can significantly improve the amount of water removed from peat by pressures less than 20 atm and using ambient or low temperatures. The organic material in the expressed water can be used as a substrate to produce the biological agents for de-watering. Hence, the process is referred to as self-contained, as the additives are produced from the waste-water stream while reducing the BOD to an acceptable level.

Preliminary economic calculations demonstrated that this process is competitive with other processes which use thermal pretreatment. There is also good potential for using biological agents to improve other pretreatment processes. Thermal pretreatment methods have been proposed by J.P. Energy, I.G.T., Zimpro, Ontario Research Foundation and the University of Sherbrooke and they all have appreciable waste treatment requirements. The addition of biological agents to the peat in these processes would be expected to minimize the waste treatment by reducing the severity of the various methods of pretreatment. There is also excellent potential for utilizing the soluble carbon compounds in the expressed water as growth substrates to produce biopolymers, etc.

Thus, our research has wide applicability. It is not limited to a single process and could be used to augment other methods of peat treatment.

Résumé administratif

Les recherches décrites dans le présent rapport ont démontré que plusieurs types de composés biologiques (notamment des polymères, des agents tensio-actifs et des enzymes) pouvaient améliorer grandement l'essorage mécanique de la tourbe devant servir de combustible. Le chitosane et la surfactine sont les composés qui ont donné les résultats les plus prometteurs. Le chitosane est un polysaccharide qui contient des sucres aminés. Lorsque ses amines forment des sels quaternaires, le polymère se transforme en polyélectrolyte dont la chaîne porte des charges positives. La surfactine est un agent tensio-actif, synthésisé par Bacillus subtilis, qui entraîne une baisse extrême de la tension superficielle de l'eau, soit jusqu'à 27 mN/m. Elle permet aussi d'étaler une solution aqueuse sur les cires extraites de la tourbe. La tourbe de Barrington (N.-E.) a été la plus difficile à essorer parmi celles qui ont été examinées dans la présente étude. Il s'agit d'une tourbe très décomposée (H9 sur l'échelle de von Post). Le traitement de cette tourbe par des agents biologiques de déshydratation, avant l'étape de compression, a permis d'éliminer jusqu'à 60 % plus d'eau.

Une étude préliminaire a révélé que la combinaison du prétraitement thermique et du traitement biologique donnait un essorage plus efficace que l'un ou l'autre de ces traitements appliqués seuls. En comprimant la tourbe de Barrington après l'avoir fait chauffer à 125°C pendant 20 min, on a pu augmenter la quantité d'eau extraite de 60 %. Avec l'addition d'agents biologiques entre les étapes de chauffage et de compression de la tourbe, la quantité d'eau libérée a augmenté de 100 %, ce qui a permis d'obtenir une teneur en humidité de 61 %, comparativement à 78-80 % dans le cas des témoins.

L'eau exprimée des divers échantillons de tourbe au moyen d'additifs et de traitements divers contenait des solides carbonés dissous ou en suspension. En ajoutant de petites quantités d'autres éléments nutritifs à ces échantillons d'eau, on a réussi à cultiver de nombreuses bactéries et levures. En fournissant à ces microorganismes les substances exprimées de la tourbe qui induisent une DBO comme source de carbone, on a pu obtenir une importante quantité de biopolymères et d'agents tensio-actifs biologiques. On a ainsi produit, en particulier, deux agents de déshydratation, le chitosane et la surfactine.

Grâce aux recherches, la faisabilité technique d'un procédé "autonome" a été démontrée. Certaines substances biologiques permettent d'éliminer sensiblement plus d'eau de la tourbe à des pressions inférieures à 20 atm et à la température ambiante ou à faible température. La portion organique de l'eau exprimée de la tourbe peut servir de substrat pour produire des agents biologiques de déshydratation. Le procédé est qualifié d'autonome puisqu'on produit les additifs à partir du courant d'eau usée tout en ramenant la DBO à un niveau acceptable.

L'analyse économique préliminaire conclut que le procédé est compétitif par rapport aux autres méthodes qui comportent un pré-traitement thermique. Il est aussi fort possible qu'on puisse améliorer les autres méthodes de pré-traitement grâce aux agents biologiques. J.P. Energy, I.G.T., Zimpro, l'Ontario Research Foundation et l'Université de Sherbrooke ont proposé des méthodes de pré-traitement thermique qui exigent toutes un traitement appréciable des effluents. On s'attend que l'addition d'agents biologiques à la tourbe au cours de ces traitements réduise au minimum le traitement des effluents en allégeant les diverses méthodes de pré-traitement. Ces agents offrent aussi d'excellentes perspectives en ce qui concerne l'utilisation de composés carbonés solubles se trouvant dans l'eau exprimée de la tourbe comme substrats de croissance pour produire des biopolymères, etc. Nos recherches présentent donc un large éventail d'applications. Elles ne sont pas limitées à un procédé unique et elles pourraient servir à améliorer d'autres méthodes de traitement de la tourbe.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 PEAT AND PEAT BOGS

As costs rise and reserves of petroleum and coal diminish, alternative energy sources and alternative chemical feedstocks are becoming more important. One of these alternatives is peat. Presently, peat is being used as a commercial energy source in Finland, Ireland and Russia. Prior to 1960, peat was used as an energy source in Denmark, Sweden, the Netherlands and Germany but after 1960 other fossil fuels had replaced peat as an energy source. Therefore, all nations, including Canada, that have significant peat resources have proceeded to reexamine the commercial utilization of peat.

Peat is a worldwide resource with estimates of more than 1000 million acres of peatlands (1) of which 170 million hectares are located in Canada. There are a variety of uses for peat. Peat coke is produced in Finland and Germany for the metallurgical industry while Ireland and the Netherlands manufacture activated carbon from peat. The Soviet Union has a very diverse peat industry which produces waxes, sugars for yeast production and other chemical feedstocks. However in Canada, peat is mined almost exclusively for horticultural purposes.

Peatlands are organic wetlands which have formed under specific biologic, geologic and climatic influences. The wetness and the accumulated plant debris at the surface limits air access to the underlying layers of decaying vegetation in the bogs. Therefore, the oxygen that is present has been completely consumed by the disintegrating plant tissues and the microbes that promote decomposition just below the wet surface. Any decay below this level must proceed anaerobically, that is microorganisms in these strata depend on the oxidizing potential stored in the plant residues. At even greater depths, this source has also been consumed and at this point the decomposition process ceases. The disintegration process stops before completion and partially decomposed plant tissues remain at the bottom of the bog.

The large peat deposits of Europe, Asia and North America date from the last Ice Age. The peat at the bottom of these bogs is less than 10,000 years old (2). The rate of peat accumulation varies from bog to bog but most commercially interesting deposits are about 3 meters thick. It takes approximately 3000 to 4000 years to accumulate one meter of peat. Some areas have very thick deposits of over 12 meters in depth and even thicknesses of 50-70 meters have been reported in Greece and Spain (3).

The accumulation of peat will continue as long as bog plants can live and die at the surface. The drainage and mining of peat terminates the process so, unlike a forest, peat is not a renewable resource. However, unlike a coal deposit, if the bog is left untouched it will continue to grow.

The composition of peat varies from bog to bog. It varies also with location and depth within an individual peat bog. Peat is composed of mostly water with only 10-20% organic matter present. In order to determine if a particular bog has commercial applications some basic observations of the geological, botanical and physicochemical characteristics of the peat must be made. The geological factor of greatest importance is the relationship between the water in the peat deposit to the groundwater system of adjacent mineral soils. If the bog water system is continuous with the mineral and groundwater system then the peatland is classified as either low-moor or transitional in character. The difference between these two classifications is that a low-moor bog is more likely to be covered with water and therefore slightly wetter than a transitional moor. Peat deposits significantly higher than the groundwater system for mineral soils are called high-moor peats. The groundwater system controls the availability of dissolved inorganic materials to the bog plants. For low-moor bogs the bog water system can carry these minerals from the mineral soils directly to the bog plants. However, high-moor bogs receive their water supply directly from rain or snow and therefore the mineral content of the water is considerably lower.

High-moor peats usually consist of mosses (Sphagnum), cotton-grass (Eriophorum) and heath plants (various genera of Ericaceae). Not all high-moor bogs have all of these plants but most contain Sphagnum. The composition of low-moor peats is different and they contain frondiferous mosses (Hypnum), reeds (Phragmites), sedges (Carex) and woody plants such as alder (Almus), willow (Salix), birch (Betula) and lowland conifers. Other plants such as the rush (Scheuchzeria) and bulrushes (Scripus) may be found in both low and high-moor peatlands. Other peat types, sedimentary or lake peats and sapropel, which are deposited at the bottom of lakes and ponds, are of little use for the energy or the chemical industry due to their high mineral and low organic contents.

The development of the botanical classification of peat deposits has been prominent in the Soviet Union (4). Their system has three main categories: low-moor, transitional and high- moor. Each category has six subgroups: woody, woody-grassy, woody-mossy, grassy, grassy-mossy and mossy and each subgroup is further classified by the dominant species or genus. There are 38 classes. Low-moor peats are mostly classified by reed-sedge vegetation with a large minority also being woody. High-moor peats, however, are characterized predominantly by one or more varieties of Sphagnum.

It must be noted that this classification system pertains only to the peats of northern and temperate climatic regions since tropical and semitropical areas are characterized by other vegetation types such as mangrove and cypress.

1.2 PEAT HUMIFICATION

The physicochemical state of peat that is the degree to which the fibrous content of the bog plants has decomposed into nonfibrous solids is also very important. This process of decomposition is usually called humification. In 1925, von Post developed a peat humification scale as a means of classifying peat (5). Decomposition corresponds to the replacement of the fibrous structure of the plant tissue by very fine particles of no regular shape. A von Post system test involves the squeezing by hand of a fresh wet peat sample. This ten grade scale (Table 1.1) is complex and somewhat subjective.

Table 1.1. The von Post and IPS Systems for the Classification of Peat by the Degree of Humification

von Post System		IPS System
Scale	Description (Water pressed from hand; residue left in hand)	
H1	Clear colourless water; characteristic plant structures	FIBRIC Mostly Sphagnum High Fibre Content
H2	Yellow-brown water; Identifiable plant residue	"
H3	Cloudy brown water; Plant residues, but no mud	"
H4	Very turbid, brown water; Muddy portions visible	HEMIC Mostly Reed-Sedge Moderate Fibre Content
H5	Very turbid with some coarser peat solids, brown water; Muddy, plant residues still identifiable	"
H6	One-third of peat is lost in the water; Very muddy, plant residues still identifiable	"
H7	One-half of peat is lost in the water; Very muddy, plant residues still identifiable	SAPRIC Low Fibre Content Often High Ash
H8	Two-thirds of peat lost in the water; Only roots, wood, Coarse fibers	"
H9	Nine-tenths of peat lost in the water; Only a few isolated plant residues	"
H10	Entire mass slips through fingers; no residue	"

A more recent system by the International Peat Society (IPS) (6) is also based on decomposition but contains only three classes (Table 1.1.). Other tests for the estimates of the degree of humification have also been devised. Varlygin's method (7) uses a thin fresh layer of peat which is examined under a microscope from over 30 separate fields of vision. Another technique is based on the hydrolysis of hemicelluloses and celluloses and then measuring the undissolved residue (8). Low-moor peats are typically 25-45% decomposed while high-moor peats are usually less than 25% decomposed.

The botanical and chemical observations of peat can be used to determine whether they are best suited for fuel use or chemical production uses. A high content of "fixed carbon", that is, the carbon residue remaining when a peat sample is pyrolyzed in the absence of air, is of importance in determining combustion properties. This property could be used to estimate the yield of peat coke. The peat ash can also indicate the quality of activated carbon produced from a peat sample. High-moor sphagnum peats which are only slightly decomposed contain large amounts of oxygen and lower levels of carbon and hydrogen and so are well suited for processes such as yeast culture production which require large amounts of carbohydrates. Conversely, low-moor peats decompose rapidly yielding material rich in carbon, therefore, making these peats more attractive for fuel uses. However, for some chemical and fuel uses, both types of peat can be utilized. In these cases the most important component is humic acids.

The difference in chemical composition of peats is based on the death and decomposition of the bog plants.

The living plants contain proteins, carbohydrates, lipids and polyphenols and lesser amounts of nucleic acids, pigments, alkaloids, vitamins and other organic substances. When the plant dies the sugars in the plant tissue are quickly released and consumed by microorganisms as are the starches. Other components such as hemicelluloses, pectins and gums are attacked more slowly and varying amounts survive along with the cellulose to form some of the peat framework.

Proteins are mostly consumed by the microorganisms of decay. The nitrogen content of these proteins is mostly leached away from the insoluble residue as ammonium salts but some in the form of amino acids or their derivatives aid in the production of humic acids.

The various lipids present in the living plants are insoluble in water. Although the vegetable oils, usually triglycerides, hydrolyze during decomposition to produce fatty acids and glycerol, only the latter is consumed as a carbon and oxygen source for microorganisms. The residual fatty acids and other surviving lipids such as waxes and steroids, form another segment of the peat composition. These materials as a group are known as bitumens. Low-moor peats very often have high bitumen contents; this is rarely so for high-moor peats.

Another relatively stable portion of the plant composition during decomposition is lignin. Since lignin is a polyphenolic material, it is usually grouped with the humic acids which are also polyphenolic in character.

Humic acids comprise the major fraction of peat but they are not present in living plants. How they occur is not certain. They possibly originate from lignin or they may be a microbial product made from components other than lignin. Although humic acids have phenolic elements in their structure, unlike lignin, they also have a high carboxylic content and significant amounts of nitrogen.

The humus content of peat, that is the amounts of humic acids and their derivatives, is extremely important in the mechanical de-watering of peat. As the humus content increases, the ability to remove water from the peat mechanically decreases. This phenomenon is due to the colloidal property of the humus material. Peat consists of a predominantly fibrous element and a secondary amorphous-granular element (9). The amorphorus-granular portion of the peat is normally a coagel of degenerated organic matter and a small quantity of mineral substances of a colloidal size. The disperse phase in this condition forms a continuous lattice, whose nuclei contain a colloidal solution of the peaty substance. Depending upon the size of the particles, this peat is essentially a polydisperse system, with the water being the dispersing medium. The disperse solid phase consists of vegetable remains and their decomposition products such as humic acids. Therefore as humic acid concentration in peat increases, the colloidal properties of peat also increases and less water can be removed by mechanical de-watering. If a substance can be added to the peat which would reduce this colloidal phenomenon, enhanced mechanical de-watering should be achieved.

Each peat bog has all or some of these organic components previously discussed but relative amounts depend on the degree of decomposition as can be seen by the elemental analyses of various peat types (Table 1.2.). In addition to this organic material, there is a smaller inorganic component. Also, the microorganisms present during decomposition also die and contribute to the total make up of the peat.

TABLE 1.2. ELEMENTAL COMPOSITION OF PEAT (% OF DRY ORGANIC MATERIAL)

ORGANIC ELEMENT	SLIGHTLY DECOMPOSED SPHAGNUM PEAT	HIGHLY DECOMPOSED SPHAGNUM PEAT	HIGHLY DECOMPOSED LOW-MOOR PEAT
Carbon	48-53	56-58	59-63
Hydrogen	5.0-6.1	5.5-6.1	5.1-6.1
Oxygen	40-46	34-49	31-34
Nitrogen	0.5-1.0	0.8-1.1	0.9-1.9
Sulphur	0.1-0.2	0.1-0.3	0.2-0.5

1.3. PEAT WAXES

As the dead bog plants disintegrate to form humification products, the resin and wax parts of these plants are accumulating in the peat without being decomposed to the same extent as the other plant material. Therefore the more humified peats possess a higher quantity of crude wax although one study using two peat samples with similar botanical composition and ash content indicated that the two peat samples had very different wax content and composition (10).

Collectively these waxes and resins are often called bitumens. Bitumen is the component of peat which dissolves in hot organic solvents. This mixture can be further separated into its own substituents by the selection of different organic solvents.

Peat wax is a mixture of esters, acids, alcohols and hydrocarbons derived from the peat which are soluble in aliphatic hydrocarbons. It is a nontacky, water-repellent solid at room temperature. Resins, another substituent class, can be extracted from the bitumen by their solubility in low-boiling alcohols. Another part of the bitumen, asphalts are characterized by their insolubility in light petroleum ether or in hot methanol.

Peat can be extracted with a nonpolar solvent primarily to recover waxes and other materials which are soluble in such systems. This extraction removes water-repellent materials from the surfaces of peat particles and therefore prepares the peat for further treatment with aqueous reagents. Since water accounts for the majority of matter in peat, it may be surprising that these water-repellent materials can interfere in the treatment of peat with water or aqueous reagents. It has, however, been demonstrated that the presence of waxes in or on individual particles will serve to retard the water penetration of the peat particles (11).

If these waxes can prevent penetration of incoming water or aqueous solutions, it also may stop water from being removed during de-watering processes.

CHAPTER 2

PEAT DE-WATERING

2. PEAT DE-WATERING

The largest obstacle for commercial peat utilization is the removal of the high amount of associated water in the peat. Peat in situ generally contains more than 90% water and in order to make it an acceptable feedstock for energy utilization, its water content must be reduced to in the order of 50%. This affinity for water which peat displays is due to several mecha- nisms, such as, hydrogen bonding, solvation of colloids and retention by capillary forces. Conventionally, two techniques are used to disrupt these forces - mechanical force and the application of thermal energy.

Most de-watering methods employed make use of solar energy at the time of mining which can reduce the water content to 30-50%. Milled peat and sod peat mining techniques allow the mined peat to dry on the surface of the bog before being transported for utilization. There are drawbacks to this system. The climate of the region may not allow for an economical mining season. Also, the scale of a proposed operation would necessitate an enormous area to be worked, since only a thin layer of the bog surface could be mined each season. Finally, there are environmental problems such as wind-borne dust, interruption of natural environments for long periods during the mining operation and the possibility of bog fires. De-watering of peat without the use of solar drying would require at least a two step process. The peat would be mined and then conveyed to a processing plant where it would be de-watered by pressing and other methods.

2.1. MECHANICAL DE-WATERING

Many mechanical de-watering methods have been used, such as roll presses, filter presses, screw presses, centrifuges and screens.

The affinity of peat for water requires high pressure in order to reduce the water to the 70% level. An optimum combination of high capacity and pressure is needed. Centrifuges, screens and vacuum filters are considered low-pressure applications. Roller and belt presses have an advantage in the de-watering of peat since these are continuous processes. Although filter and screw presses may reduce the water content as low or even lower than roller or belt processes, their capacity is much less than that of continuous methods. The capacity of a variable nip twin roll press in dry tons per day can be 6 times that of a screw press and 5 times that of an automatic filter press.

Screening and centrifuge techniques are useful if the de-watering plant receives a dilute slurry that is one containing 1% peat since it initially removes substantial amounts of water and increases the amount of peat that can be handled in subsequent pressing.

A variable nip press consists of two horizontal rolls mounted in a sealed vat. One roll is fixed and the other is movable to allow for variable nip openings. If the mat thickness changes, the movable roll compensates and maintains a constant nip load, resulting in a constant discharge of solids. The peat slurry, at an incoming solids concentration of approximately 3 to 5%, enters the sealed vat at a pressure of between 0.20 to 0.34 atm. The slurry drains by pressure filtration and is then carried into the nip where it is further de-watered to the desired dryness of up to 40% solids.

In a "multi-nip" press, the peat is moved through the machine on belts. The press applies increasing pressure on the peat by a series of paired rollers. In the final stages pressures as high as 40 atm are applied to maximize the extraction of water.

2.2. THERMAL DRYING

There are three types of thermal dryers which can be used for the drying of peat and all can be designed with combustors to use peat as a fuel. They are rotary drum, fluidized-bed and flash dryers. All three are being commercially used for the production of commercial peat moss but the scales of operation for that application are quite small.

In a rotary drum dryer, the peat is tumbled and cascaded through a heated gas stream. These dryers can be designed as a single-pass or a triple-pass mechanism. Since these dryers cannot be manufactured on site, their size is limited by shipping requirements and this is a problem for any large scale process.

In fluidized-bed dryers, gas velocities are relatively low and this results in a minimum formation of fines. The temperature differences between the solids and the surrounding gas can be less than those for rotary or flash dryers because of the excellent conditions for mass transfer. Low maintenance costs are due to a lack of moving parts and the low velocities used. The advantages of this process are the minimum thermal degradation and minimum comminution of particles.

Flash dryers have been found suitable for drying both horticultural peat moss and fuel peats. A commercial operation in Finland has a 43,182 kg per hr. capacity for drying milled peat from 55 to 30% water content (12). The high velocity and turbulence of the gas flow in the flash dryer causes more comminution than in either rotary or fluidized-bed dryers. Flash dryers can be field assembled and therefore large units do not present a problem.

A commercial thermo-mechanical method of de-watering of peat has been located at Fisons Western Corp., Vancouver. The peat was transported from the bog as a slurry, de-watered to in the order of 70% water content by mechanical pressing, and followed by flash drying to 55% moisture.

Another technique involves the mixing of predried peat (25-40% water content) with peat from the bog. The colloidal character of the raw peat may be altered by the addition of the finely divided material. A plant in Bavaria, West Germany, uses this technique to mechanically de-water the peat to 60% moisture which can be further de-watered by thermal drying.

2.3. SOLVENT EXTRACTION DE-WATERING

The Institute of Gas Technology (IGT), Chicago Ill., is studying the utilization of solvent extraction as a peat de-watering technique. It is based on the principle that in a certain solvent water has a higher solubility at higher temperatures and a lower solubility at lower temperatures. In this process peat is contacted with the solvent at a high temperature. Water accompanying the peat dissolves in the solvent and the mixture is decanted and allowed to cool.

The solubility of the water decreases and the mixture separates into a water-rich layer and a solvent-rich layer. Before being discharged the water-rich layer is sent to a solvent recovery system while the solvent-rich layer is returned to the process and mixed with a fresh peat sample. Solvent remaining with the peat and its retained water is vaporized in a dryer and collected for reuse.

2.4. WET CARBONIZATION

A peat-water slurry is heated at 200°C and 25 atm in this method. The chemical changes which occur allow the peat to be mechanically de-watered to approximately 50%. This technique forms the basis of the Finnish JP-Energy process (13). Subjection of the peat to this technique disrupts the colloidal structure of the peat and oxygen is released as carbon dioxide and water. This process can reduce the water content of the peat to 50%.

2.5 WET OXIDATION

Wet oxidation is combustion in the presence of water and it is used for the oxidation of organic materials and industrial wastes. Oxygen or air is supplied at high pressure to the peat in a heated, stirred pressurized vessel. Combustion is fast and is controlled by the rate of oxygen supplied. The process can be allowed to continue to completion to produce energy or it can be stopped when enough heat is generated to affect wet carbonization. The treated peat can now be mechanically de-watered to less than 50% (14).

2.6. PEAT BENEFICIATION

The quality of a low-grade fuel is enhanced by beneficiation processes which can increase its ease of handling, its heating value and, particularly important for peat, reduce water content. Available techniques for beneficiation of peat include:

1) drying and briquetting of milled peat, yielding an easy-to handle, dense fuel of low (10-15%) moisture content;
2) drying and coking sod peat, resulting in a premium product suitable for electro-metallurgical applications or as a substitute for charcoal in chemical processing;
3) wet carbonization of wet-mined peat resulting in easier dewatering and improved heating value; and
4) wet pyrolysis of wet mined peat, yielding a much improved pelletized fuel plus an additional tar fraction.

In the manufacture of briquettes, mined milled peat of 40-55% water content (field dried) is transported from the bog to the plant where it is further dried using a flash dryer and fluidized bed combustion unit.

Peat coke is produced by the carbonization of field-dried peat sods of well humified *Sphagnum* peat. The most common industrial uses are as a reductant in metallurgical processes and as a starting material for the production of activated carbon.

The wet carbonization of peat using the JP-Energy process has difficulties arising from the fouling of heat exchanger surfaces in the plant and also in the treatment of the waste water from the process.

The Koppelman Wet Pyrolysis process can be applied to the de-watering and upgrading of a variety of high moisture, low-heating value fuels. The process transforms these peats into dry high heating value fuels with low sulphur contents. In this process the peat is passed through an externally heated tube. The water vaporizes and the temperature of the peat increases which causes mild pyrolysis. The tarry pyrolysis products adhere to the solid materials and eventually partially carbonize. The gases produced from the process are used to heat the reaction tube. Before the final cooling, the pyrolyzed product can be pelletized.

2.7. POLLUTION POTENTIAL OF AQUEOUS EFFLUENTS FROM PEAT

The de-watering of peat leads to large quantities of expressed water. Little effort has been made to characterize the potential pollution hazard. Suspended solids, colour, pH, phenol concentration and organic content render the water unsafe to be returned to bog areas or to surface and subsurface streams. Water treatment is then necessary and this imposes a severe economic penalty on the overall process. The ultimate goal, as in any water treatment process, is to lower the COD (chemical oxygen demand), toxicity, etc. for as little cost as possible.

Pressing peat without heat pretreatment does not change the peat chemically but peat particles and dissolved organics will be released with the water. Several forms of treatment are then necessary: suspended solids can be removed by sedimentation and the pH raised from 4 to 7. The removal of dissolved organic material and the colour is more difficult and more expensive.

Heat treatments have been used to improve the de-watering ability of peat by breaking its colloidal structure. Organic content and toxicity of the expressed water are increased substantially by these high temperatures (15). Colour is especially noticeable changing from pale yellow to dark brown.

2.7.1. WET CARBONIZATION

Wet carbonization is one form of heat pretreatment used. High temperatures and pressures such as in the case of the JP-Energy process, 200°C and 20 atm, are utilized (15). The peat is broken down into lower molecular weight compounds which are now dissolved in the water (15). Although no data are available from working de-watering plants, some are shown for laboratory scale experiments. Smith (15) estimates that a 1000 tonne/hr raw peat plant will yield a stream of 918.8 tonnes/hr of liquid effluent of which 8050 ppm is soluble organics. Eighty per cent is methanol, acetone and acetic acids (16). Phenol content is 218 mg/L. Only 60% of the dry peat mass is recovered after pressing, the rest remains mostly in the effluent. The COD is 21,000 mg/L, a very high value (17).

For such high organic content streams, an anaerobic/aerobic biological treatment is necessary (16). The anaerobic step consists of 2 stages. Organic acids are produced and then converted to methane. This is a relatively low value product. Examples of this type of treatment with other high strength wastes such as distillery and sugar beet wastes demonstrate problems such as difficulty in starting up, long time requirement for treatment, sensitivity to toxic substances and temperatures and inability to convert some organics (18). A polishing lagoon is then used for tertiary treatment. Even though a credit for methane is taken, the total cost of effluent treatment is large at $15.49/tonne of dry peat processed (17). (300,000 dry tonne peat per year plant).

The Koppelman process is even more severe requiring a temperature and pressure of 400°C and 100 atm (15). This effluent gives a stream with a COD of 24,550 mg/L (17). Very little data are available on the composition of the stream except that phenols have a concentration of 924 mg/L. It is expected, though, that a similar treatment process to the JP-Energy would be necessary.

Another carbonization process developed by Chornet (19) is known as low severity de-watering. The peat is added to a continuous flow reactor at 190°C for less than one minute. Although, the composition of the effluent is unknown, COD values were determined at 2 different temperatures. At 90°C it is 1790 mg/L and at 190°C it is 14,300 mg/L. Lower temperatures result in substantially lower COD values.

2.7.2. PARTIAL WET OXIDATION

Using the partial wet oxidation process, combustion occurs at a temperature of 200°C until the colloidal structure of the peat has been destroyed for de-watering purposes (16). From a 1000 tonne/hr production rate of peat slurry, 878.3 tonnes /hr of wastewater are produced (15). The anaerobic/aerobic digestion process developed by Sheppard and McKim (20) as bench scale experiments would be necessary.

2.7.3. OTHER DE-WATERING PROCESSES

Other de-watering techniques have also been investigated. Solvent extraction although technically feasible is not economically competitive (21). Centrifugation and multiple effect evaporation are not well developed. Hence, no information on water effluents has been given. The Zimpro process is another partial oxidation de-watering system (17). Since the slurry is not totally oxidized, the COD is lower than expected but is still high at 9400 mg/L. Costs of effluent treatment have not been estimated for this process but the ORP-Wetox process, another partial oxidation system, requires anaerobic treatment and costs $16.88/tonne of dried peat for a 25,000 dry tonne of peat per year plant, comparable to the JP-Energy process (17).

CHAPTER 3

PROJECT BACKGROUND

3. PROJECT BACKGROUND

3.1. POLYELECTROLYTES AND THEIR ROLE IN FLOCCULATION

Colloids due to their small size cannot be removed from liquids in the usual way by centrifugation, filtration and sedimentation. The particle size must be increased by coagulation which is neutralization of charge and formation of microflocs and flocculation which is the bridging together of small particles to form larger particles (22).

Polyelectrolytes are charged polymers that can be used to induce coagulation and/or flocculation. They can be either natural or synthetic and vary according to molecular weight from a few to 10 million. The polymer can be linear or may contain branching of the chains and they also may have ionizable groups at various locations on the chain.

Usually, polyelectrolytes are classified as anionic, cationic or non-ionic. If the polymer retains a negative charge on the chain after ionization, it is referred to as an anionic polyelectrolyte. Its functional groups are either carboxylic or sulfonic (23),(24). Similarly polymers are called cationic polyelectrolytes when a positive charge is retained by chain after ionization of amine or pyridine functional groups. Polymers without charged sites are referred to as non-ionic and contain amide, hydroxy, hydroxyalkyl ether and/or alkoxy groups.

Due to their ease of handling and efficiency, use of polyelectrolytes over inorganic salts is increasing in water treatment operations. They are also less toxic. Although they generally have high unit costs ($0.40 to $2.50 per lb in 1978 U.S. dollars)

(26) the dosage required is much less - only 0.1 to 1 mg/L is necessary as compared to 10-60 mg/L. Equipment sizing can also be reduced. To break even, 1 ppm of cationic polymer must replace 10 to 15 ppm of alum (27).

The colloidal characteristics of peat suggest that polyelectrolytes may be able to enhance de-watering by disrupting the colloidal structures. It is known that most natural colloids like peat are negatively charged and it is this charge that is largely responsible for the stability of such colloids (25). The electrostatic repulsion between particles dominates over the van der Waal's attraction forces according to the theory postulated by Derjaguin, Landau, Vervey and Overbeek. These attraction forces would allow the small colloidal particles to agglomerate, making them large enough to settle rapidly. Coagulation-flocculation destabilizes the colloids by adsorption of the polyelectrolyte onto the colloid surface reducing charge and bridging between particles.

Each particle has an electrical double layer and it is their overlapping that causes repulsion (29). The inner layer consists of ions of opposite charge to the surface called counterions which move with the particle and not the fluid, causing a potential difference with the solution called the zeta potential. The boundary of mobility is the shear plane. The outer layer contains a smaller concentration of ions. Higher counterion charges and concentrations lower the zeta potential. The potential difference occurs because of ionization of surface groups on the particle, ion adsorption or ion dissolution mechanisms (30).

Larger double layer thicknesses increase the distance to which another particle can approach. The system is then stable. In terms of potential energy, a system where the potential energy maximum is larger than a thermal system (Brownian motion) is stable (29).

Reducing the repulsion between particles increases the likelihood they will coagulate. This can be accomplished by reducing the double layer thickness (30). Addition of a polyelectrolyte compresses the diffuse parts of the double layer around the particles and may even cause ion adsorption. The increased counterion concentration lowers the zeta potential and allows particles to approach close enough for van der Waal's forces to predominate.

The polyelectrolyte reduces the charge when adsorbed on to the surface. Cationic polymers are utilized to destabilize the colloidal system of negatively charged particles. The potential energy maximum is lowered (29). The concentration at which it is zero is called the critical coagulation concentration. It is only dependent on counterion charge.

The flocculation step occurs when bridging takes place which is the attaching of 2 or more colloids by a polymer. Loose 3 dimensional networks are formed into large masses for rapid solid-water separation. Each polymer has thousands of ionically charged sites for neutralization but hydrogen bonding sites are utilized for the bridging (22).

Theories of adsorption assume that the polymer attached to one particle can still attach to similar particles since the polymer still has free active centres for adsorption (31). The rate of floc formation depends on the amount of particles with the polymer and the free surface on the particles. As adsorption sites are taken up the rate decreases. Too little polymer means very little bridging can take place. If too much polymer is added, the polymer will coat a particle instead of bridging between particles, therefore, not increasing colloidal size.

Linear polymers are more effective than branched for bridging possibly due to their flexibility or the fact that they have larger tail lengths. Various loops of polymer form on the colloids but it is the tails that provide the main contribution to adsorption. For high molecular weight polymers, the proportion of tails is constant and tail length is proportional to molecular weight. In acid solution, a cationic polymer with high charge density will be fully extended but in basic conditions it is more coiled making it less available for bridging (27). Increasing charge on the polymer means more extension.

All types of polyelectrolytes can partake in bridging (31). Weakly charged anionic polymers and nonionic polymers can bridge without charge neutralization even though there is repulsion but not if the repulsion is too strong. Intense short range forces are involved in adsorption. A great deal of energy is involved in moving the polymer to the surface of the particle and the solvent from the surface. Both mechanisms of bridging and charge neutralization are required for good and fast flocculation (27). Cationic polyelectrolytes can be used by themselves. Because they can do both mechanisms, smaller molecular weights can be used than anionic polymers which need tail length for bridging. To use anionics for bridging, cationics are necessary for charge neutralization. In the case of cationic particles, anionic polyelectrolytes can be used for charge neutralization.

In addition to the type of polyelectrolyte used, mixing is another important influence on flocculation. Dispersion of the polymer in the colloidal suspension is the first requirement. Also stirring increases the frequency of collision between particles and polymer, thus increasing the rate of flocculation (22). Degradation can occur, though, if the intensity of agitation is too severe. Polymer segments become shorter, decreasing bridging ability (33). Since cationic polyelectrolytes are strongly adsorbed to particles because of charge neutralization, the effect of shear is not as great as on anionic polyelectrolyte flocculation.

As a means of solid-liquid separation, coagulation-flocculation is essential in wastewater and sewage treatment. Food, paper, chemical petroleum and metal industries all use this method as an aid to filtration, sedimentation and centrifugation (29). Filtration is aided by any of three ways. As flocculated colloids are larger they can be more easily retained on the filter. In cake filtration, flocculated solids form a looser and more porous cake than non-flocculated solids. Filtration rates are increased as well as cake thicknesses. In depth filtration, the polymer is added before the sand filter to the water stream or added to the sand just before the influent water. Coagulation then occurs before or during filtration.

Large radii particles such as flocs sediment faster than smaller particles (29). It is on this principle that the use of thickeners and clarifiers is based. Thickeners are usually shallow circular vessels with gently sloping bottoms towards the center where the solids are removed. Deep core thickeners have steeper angle lower conical portions. Because they are deeper, sediments with lower water content are obtained.

Centrifugal forces remove solids in a centrifuge. An example is the continuous scroll discharge centrifuge (29). The suspension is fed into a bowl and the sedimented particles are drawn up by a scroll rotating at a slightly different speed than the centrifuge rotor. The water is discharged at the other end. Hydrocyclones have no moving parts and can remove small flocs due to the high forces involved.

In sewage treatment, polymers are well known in sludge de-watering. Thickeners with presses for de-watering of pulp, vacuum filters and centrifuges are used. The moisture content of the solids is reduced as well as the solid content in the water. These polymers can then be referred to as de-watering agents. Most plants have now replaced lime and ferric chloride in sludge de-watering (27). Cationic polyelectrolytes use dominates. A cationic copolymer of acrylamide and diallyl methyl ammonium halide is preferred for sewage vacuum filtration (34). Asano (35) has shown that Flonac, a cationic derivative of chitin/chitosan can be used with a scroll centrifuge for de-watering purposes. Other negatively charged particles like peat could then be flocculated through the use of cationic polyelectrolytes to increase the efficiency of water removal.

3.2. PROJECT OBJECTIVES

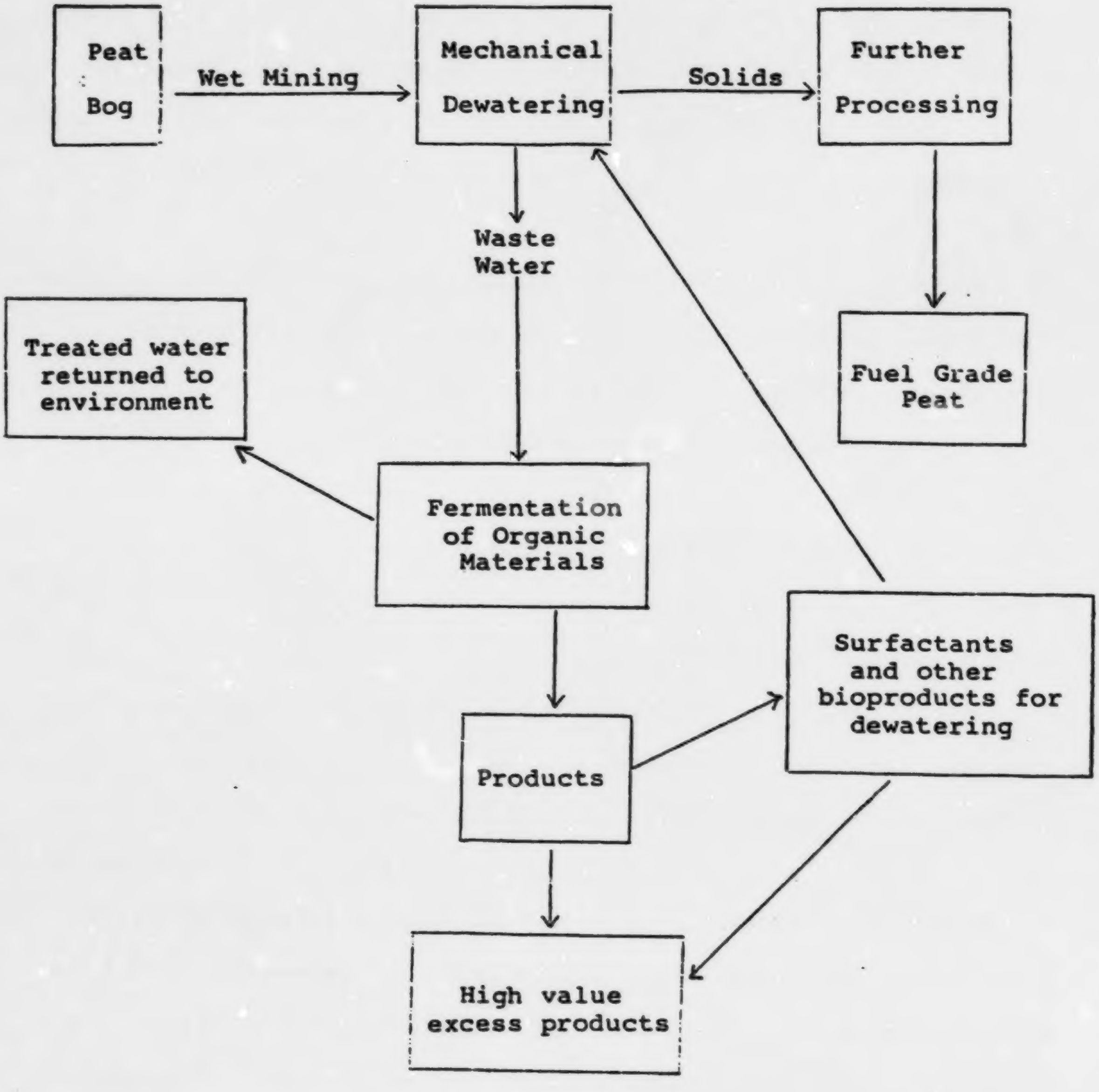
Figure 1.1 is a schematic representation of the integration of the proposed procedures in the overall process to generate fuel grade peat. The most feasible method to produce fuel grade peat in Canada would require wet mining as the first step. In order to produce a fuel grade peat, it will be necessary to substantially reduce the initial water content from the 90% of the crude product.

Mechanical de-watering can reduce the water content to about 70%. This is insufficient for combustion. The addition of the appropriate surfactant or polymer before pressing would favourably alter the binding of the water and significantly reduce the final water content. If these surface active agents were produced by fermentation of the nutrients in the displaced water, the additional cost would be negligible and there would be no deleterious effect on the final product.

After being de-watered, the peat would be further processed. However, depending on the method used, the expressed water may contain significant amounts of organic material. This could represent a significant pollution problem, but it is also a valuable feedstock for biological upgrading to many different products. In particular, the de-watering agents could be generated from this medium, therefore, completing the cycle outlined in Figure 1.1. The water could then bereturned to the environment with minimal further treatment.

Therefore, the objectives of this feasibility study are as follows:

Figure 3.1. Representation of proposed processes and their place in the overall scheme of peat dewatering


Peat Bog
Wet Mining
Mechanical Dewatering
Solids
Further Processing
Waste Water
Fuel Grade Peat
Treated water returned to environment
Fermentation of Organic Materials
Surfactants and other bioproducts for dewatering
Products
High value excess products

(a) The primary objective is to study the ability of biological products to aid in the mechanical de-watering of peat to be used as fuel.

(b) The aqueous stream from the de-watering process may be high in organic nutrients and therefore, this phase may be useful as a fermentation substrate to produce the biological agents to be used in de-watering.

(c) A relatively small amount of the nutrients in the aqueous phase will be required to produce de-watering agents. However, these products have many other applications. An important objective is to demonstrate that valuable, easily transported biological products can be obtained from the de-watering process which will significantly benefit the economics of the overall process.

(d) The expressed peat water represents a major pollution problem with a high BOD. After fermenting the organic materials to produce biological products only minimal waste water treatment would be necessary.

(e) Another objective is to study the nature of the water entrapment in the peat. An investigation of the effect that biological agents have on the physical properties (such as interfacial energies, coagulation and emulsification tests) of the peat will be performed in an attempt to correlate these properties with enhanced de-watering.

CHAPTER 4

MATERIALS AND METHODS

4. MATERIALS AND METHODS

4.1. Mechanical Press

The blueprint for a peat pressing die was obtained from the Ontario Research Foundation. The die consists of a base with a shallow excavation in which a cylinder is rested. A sintered steel filter and a support disc are inserted into the cylinder and a piston, equipped with two o-rings for a tight fit, is used to apply pressure to the peat samples. The base has an aperture to allow the pressate to escape through the bottom.

In order to apply a maximum of 30 atm of pressure on the samples, a pneumatic system, with a pneumatic cylinder of 4.5 inches, connected to a 96 psi air line was employed. A double acting cylinder was chosen so that it could be used to insert as well as retract the piston of the press.

In order to integrate the die to the pneumatic system two modifications were necessary. First the piston was fastened to the pneumatic cylinder by boring the appropriate thread into the piston and screwing the two pieces together. The second modification consisted of fastening the cylinder of the press die to the base so that it would not be retracted with the piston. This was accomplished by driving three pins through the base and letting them protrude out slightly into the shallow encavement. Three inverted "L" shaped notches were then made in the peat cylinder to allow the two pieces to be quickly fastened or separated by a twisting motion. The equipment was then mounted on a stand capable of withstanding the forces at work. All modifications and assembly were performed by the Chemical Engineering Machine Shop.

4.2. STANDARD PRESSING PROCESURE

To a peat sample of approximately 25g was added the stated amount of biological agent. This mixture was stirred at 45 rpm for 5 minutes by means of a high torque stirrer. The sample was then transferred to the peat press where it was pressed for 2.5 minutes at 19.3 atm. After pressing, the sample was immediately weighed. The sample was then dried at 105°C to a constant weight.

4.3. CONTROL PRESSING PROCEDURE

The control procedure was the same as the standard pressing procedure except that no biological agents were added.

4.4. PRESSING PROCEDURE FOR HEAT TREATED PEAT SAMPLES

These samples were heated at the temperatures indicated and for the times indicated followed by the standard pressing procedure.

4.5. CALCULATIONS OF THE WATER CONTENT OF PEAT

Water Content of the Unpressed Peat

$$\text{water content} = \frac{\text{wt of water in the sample}}{\text{wt of dry peat in the sample}} \quad (\text{kg } H_2O/\text{kg dry peat})$$

Water Content of Pressed Peat Samples

$$\text{weight of water in pressed peat} = \text{wt of pressed sample} - \text{wt of pressed sample after drying}$$

$$\%\ \text{moisture content of pressed peat} = \frac{\text{wt of water in pressed sample}}{\text{wt of pressed sample}} \times 100$$

$$\text{water content after pressing} = \frac{\text{wt of water in pressed sample}}{\text{wt of dry peat in pressed sample}} \quad (\text{kg } H_2O/\text{kg dry peat})$$

$$\text{weight of water removed by pressing} = \text{water content of unpressed peat} - \text{water content of pressed peat}$$

$$\%\ \text{water removed} = \frac{\text{wt of water removed by pressing}}{\text{wt of water in unpressed sample}} \times 100$$

4.6. PREPARATION OF THE CHLORIDE SALT OF CHITOSAN

The chitosan starting material was purchased from the Sigma Chemical Company, St. Louis, Mo. To 50 mL of concentrated hydrochloric acid was added 5 g of chitosan. The mixture was stirred and heated at 70°C for 2 hr. The solution was then cooled by means of an ice bath and acetone was added until a white precipitate appeared. The precipitate was collected by vacuum filtration and washed twice with 100 mL portions of acetone. The white solid was air dried.

4.7. GROWTH STUDIES

All growth studies were in 50 mL samples in 500 mL Erlenmyer flasks shaken at 170 rpm for 7 days. All measurements were made at the end of this period. All cultures were grown at 25°C with the exception of *Bacillus subtilis* which was grown at 37°C.

B. subtilis was grown in a medium of 4% glucose, 0.6% Na_2HPO_4, 0.4% NH_4NO_3 and 0.4% KH_2PO_4 for maximum surfactant production *Corynebacterium lepus* was grown in the same mineral salts but used 2% hexadecane as the carbon source. *Corynebacterium fascians* required the same mineral salts solution with 4% hexadecane and 0.1% yeast extract.

4.8. MEASUREMENT OF SURFACE TENSION, γ_{LV} (36)

A Fisher Autotensiomat was used to measure surface tension by the de Nuoy method. It uses a strain gauge to measure the force required to pull a platinum-iridium ring through a surface of solution.

4.9. MEASUREMENT OF EMULSIFICATION ABILITY (36)

A volume of 4 mL of broth was vortexed for 2 minutes with 6 mL of kerosene in a 12 mm diameter test tube and left for 24 hours. The ratio of the height of the emulsion zone, h_{24}, to the initial height of the mixture, h_o, was determined.

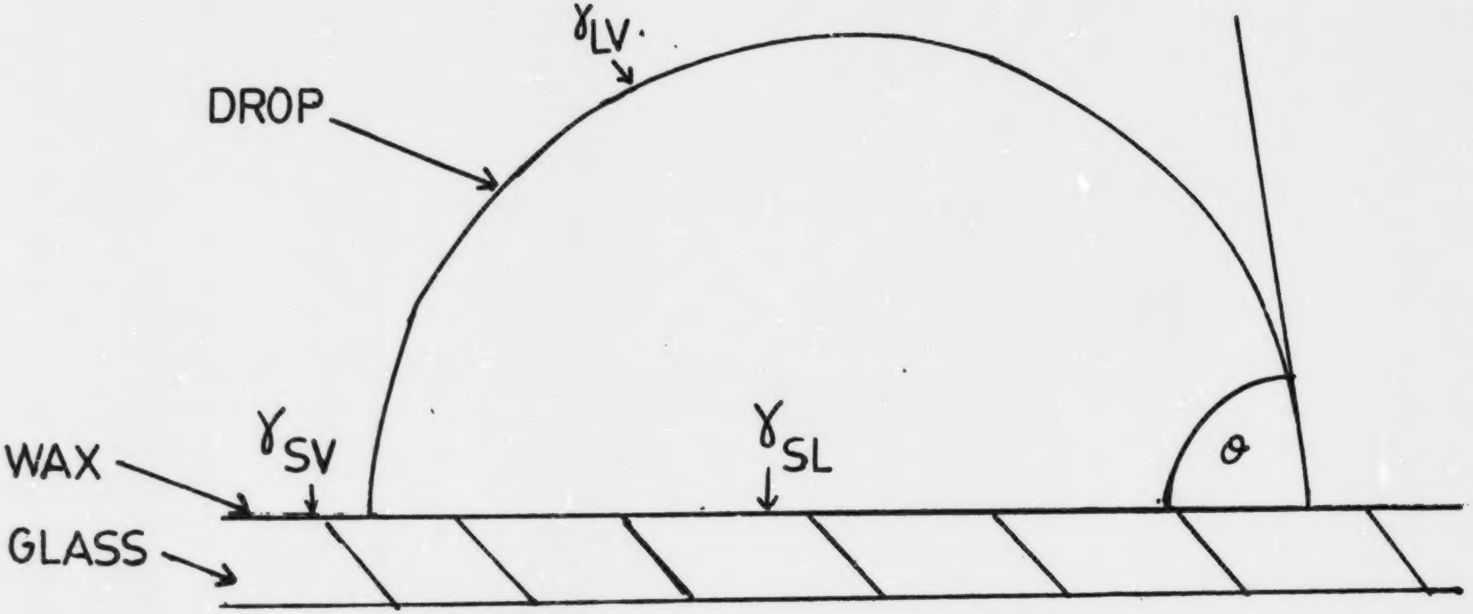
4.10. MEASUREMENT OF POLYSACCHARIDE PRODUCTION

Production of polysaccharide was determined by precipitation. Two volumes of methanol was added to one volume of cell free broth. The precipitate was then centrifuged out and redissolved in distilled water. Two volumes of methanol was again added and the precipitate removed by centrifugation. The purified polysaccharide was then dissolved in a small amount of distilled water, added to a preweighed dish, dried overnight at 105°C and reweighed.

4.11. MEASUREMENT OF CONTACT ANGLE AND DETERMINATION OF INTERFACIAL SURFACE TENSIONS (37)

A flat surface of wax was obtained by melting wax, extracted from peat by n-butanol, on a microscopic glass slide. A small drop was placed on the wax and the contact angle was measured (Figure 4.1.) by projecting the drop on the screen of a Nikon Measurescope and using a protractor to determine the angle.

FIGURE 4.1. SCHEMATIC DIAGRAM OF CONTACT ANGLE


γ_{LV}
DROP
WAX
γ_{SV}
γ_{SL}
θ
GLASS

γ_{LV} - LIQUID/VAPOUR SURFACE TENSION

γ_{SL} - SOLID/LIQUID SURFACE TENSION

γ_{SV} - SOLID/VAPOUR SURFACE TENSION

Surface tensions, γ_{SL} and γ_{SV}, were determined from the surface tension, γ_{LV}, and the contact angle using the following equations:

equation of state

$$\gamma_{SL} = \frac{(\gamma_{SV} - \gamma_{LV})^2}{1 - 0.015 \sqrt{\gamma_{SV}\, \gamma_{LV}}} \qquad (1)$$

Young's equation

$$\gamma_{SV} - \gamma_{SL} = \gamma_{LV} \cos \sigma. \qquad (2)$$

Equations (1) and (2) were combined to form equation (3) by van Oss and coworkers.

$$\cos \sigma = \frac{(0.015\, \gamma_{SV} - 2.00) \sqrt{\gamma_{SV} + \gamma_{LV}} + \gamma_{LV}}{\gamma_{LV} (0.015 \sqrt{\gamma_{SV}\, \gamma_{LV}} - 1)} \qquad (3)$$

Through a computer program, tables were generated from equations (1) and (3) to enable easy determination of γ_{SV} and γ_{SL}.

4.12. BIOMASS MEASUREMENT (38)

A broth sample of 20 mL was centrifuged for 10 minutes at 15,000 rpm. The liquid was decanted off and the cells washed to remove excess salts and recentrifuged. The cells were then resuspended in a small amount of water and added to a preweighed dish.

The cells were dried at 105°C overnight and reweighed. If peat particles were present, corrections were made for their weight.

4.13. MEASUREMENT OF PEAT SEDIMENTATION

The amount of peat sediments in a known volume of expressed peat water was measured in the same way as biomass. Samples were usually larger than 20 mL.

4.14. DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD) (39)

The method devised by Knechtel was followed entirely with a few exceptions. The digestion solution was added first then the COD solution and finally the catalyst solution. Digestion time was increased from 2 hours to 3 hours. Since most solutions had a COD higher than 1,000 mg/L, they were diluted.

CHAPTER 5

DEVELOPMENT OF THE STANDARD PRESSING CONDITIONS

5. DEVELOPMENT OF THE STANDARD PRESSING CONDITIONS

In order to maximize the effect of the addition of active reagents which were to be studied for enhanced peat de-watering, it was necessary to establish a standard pressing procedure which would approximate the optimum conditions for the mechanical pressing.

A peat sample size of 25g proved to be the best since smaller sample sizes were difficult to remove from the press.

The Quebec peat sample was used in the following control studies and it had a total water content of approximately 87%. The first variable investigated was pressing time. All samples were pressed at a pressure of 19.3 atm. The results (Table 5.1. and Figure 5.1.) showed that the water content of the peat was reduced to 72.7% when a pressing time of 2.5 minutes was used. The water content was reduced to 59.1% (Table 5.1.) when a pressing time of 15 minutes was employed but this would not be feasible for a commercial pressing operation and 2.5 minutes was selected as the standard pressing time.

The standard pressing time (2.5 minutes) was used for all samples as the applied pressure was varied. The relatively low pressures of 5.5 and 10.7 atm (Table 5.2. and Figure 5.2.) afforded peat samples with moisture contents from 77% to 79.5%. This was only a slight improvement in the moisture content of the raw peat (86.5%). However, pressures of 16 and 30 atm lowered the water content to approximately 67% (Table 5.2.). Examination of Figure 5.2., the moisture content of the peat versus pressure, clearly showed that a plateau was established at approximately 16

Table 5.1. Peat Pressing Controls[a]: Pressing Time Study (Quebec Peat)

Pressing Time (min.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
2.5	2.93	3.72	58.2	72.7
4.0	3.05	4.20	65.7	68.7
6.0	3.19	4.41	69.0	66.5
10.0	3.09	4.73	74.0	62.3
15.0	3.16	4.94	77.3	59.1

Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 86.5%

a. Each peat sample was approximately 25 g and was pressed at 19.3 atm for the specified length of time.

Figure 5.1. Pressing Time Study.

Moisture content of peat versus pressing time

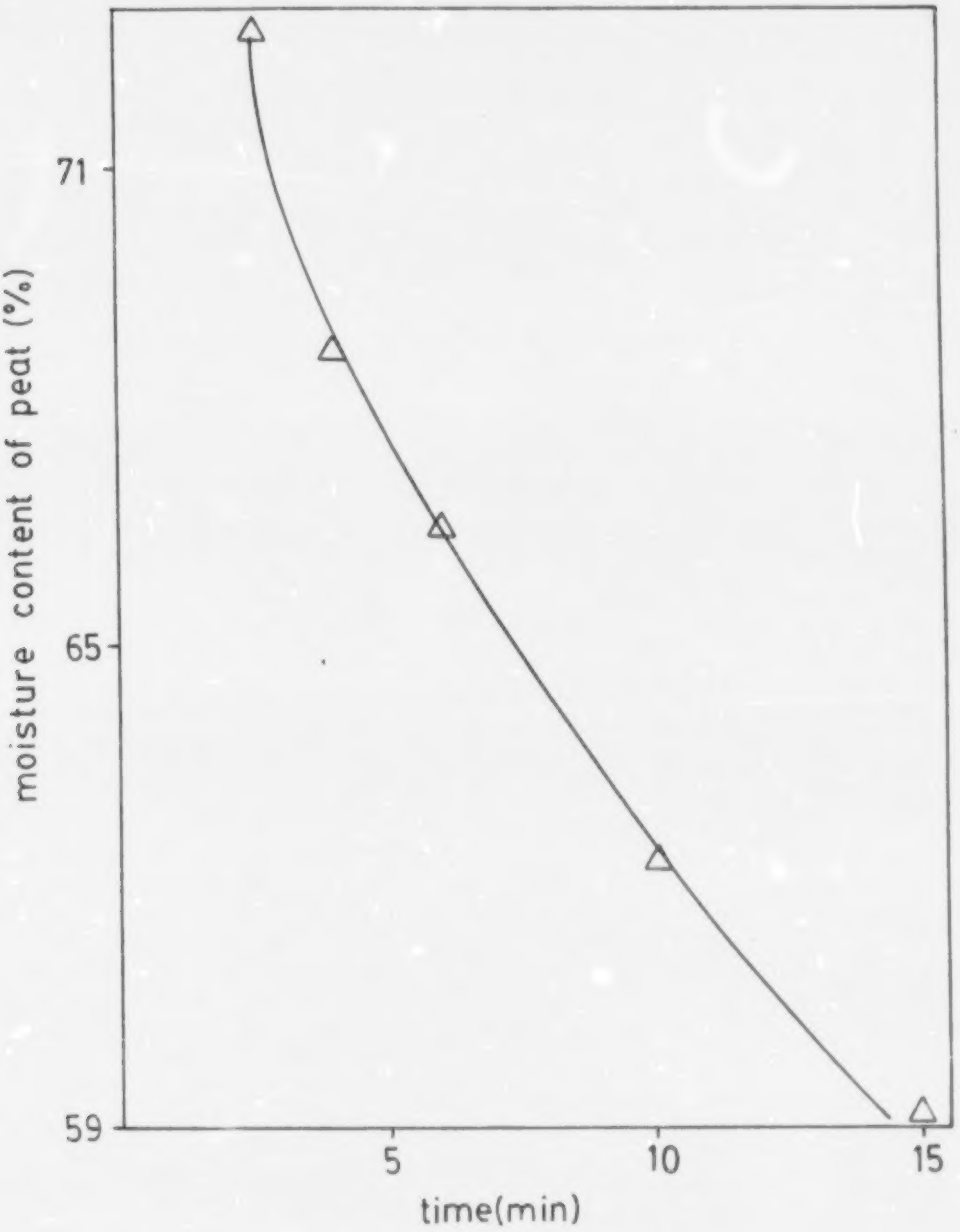


Table 5.2. Peat Pressing Controls[a]: Peat Press Pressure Study (Quebec Peat)

Pressure In Press (atm)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)	(log$_{10}$)
30	3.00	4.32	67.6	67.5	1.83
16	3.40	4.34	67.9	67.2	1.83
10.7	2.85	3.00	46.9	77.2	1.89
5.5	2.88	2.49	39.0	79.5	1.90

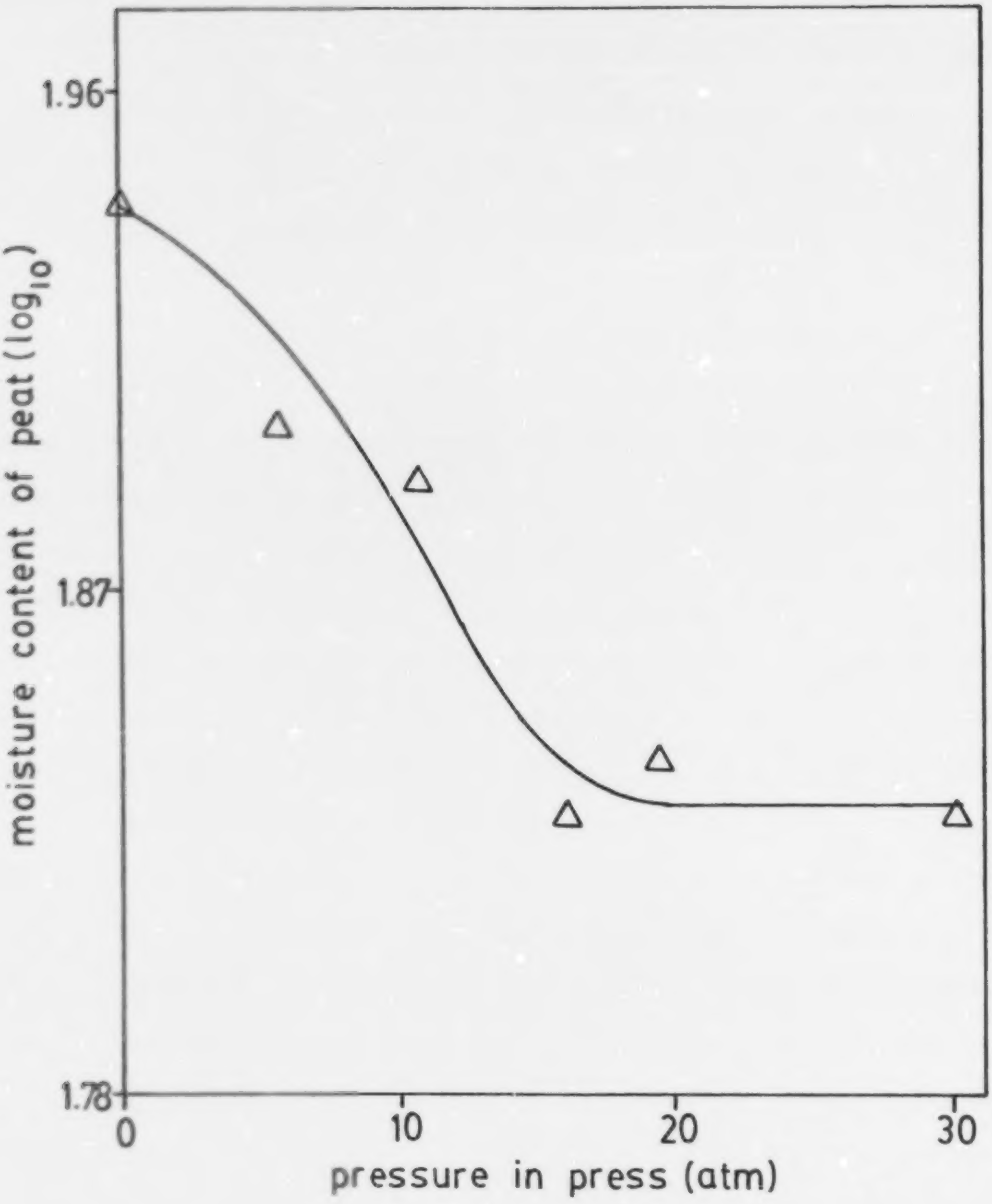
Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 86.5%; 1.94 ($\log_{10}$)

a. Each peat sample was approximately 25 g and was pressed at the specified pressure for 2.5 min.

Figure 5.2. Press Pressure Study.

Moisture content of peat versus press pressure



atm where an increase in pressure had little effect on peat de-watering. The maximum pressure acceptable for a commercial pressing operation would be 20 atm. Therefore, a pressure of 19.3 atm was selected as the standard pressure.

Therefore, the conditions for peat pressing were:

1) a peat sample size of 25g.
2) a pressing time of 2.5 minutes
3) a press pressure of 19.3 atm

Certain reagents, that were to be studied, required a pH of 7.7 to optimize their effect. Since the pH of the peat was 4.7 it was necessary to determine if the raising of the pH of the peat to 7.7 would have a negative effect on de-watering. Using the standard conditions, a peat sample was pressed without adjustment to the pH and the moisture content following pressing was found to be 74.8% (Table 5.3.). The moisture content of peat samples, whose pH's were adjusted, rose dramatically as the pH rose. However, it was possible to raise the pH to allow a reagent to work at its optimum and then lower the pH of the peat back to the original value (pH 4.7) and then press. Peat samples were pressed which had their pH's increased to 7.7 and then readjusted to 4.7. When these samples were pressed the moisture content was still extremely high (81.1%, Table 5.4.). It was therefore decided to do all studies, with reagents that worked best at a higher pH, at the normal peat pH of 4.7 since raising the pH had a very large negative effect on peat de-watering.

Finally, since reagents were going to be added to the peat samples, a means of mixing the reagents into the peat had to be

Table 5.3. Peat Pressing[a]: The Effect of pH Adjustments (Quebec Peat)

pH	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
6.7	3.27	2.30	33.9	81.8
7.3	3.16	1.97	29.0	82.9
7.5	3.04	1.99	29.3	82.8
4.7 (Control, pH unadjusted)	3.28	3.83	56.3	74.8

Total Water Content (unpressed peat) = 6.81 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 87.2%

a. Each peat sample was approximately 25 g and was pressed at 19.3 atm for 2.5 min.

Table 5.4. Peat Pressing[a]: Effect of pH Readjustment on De-watering (Quebec peat)

pH Adjustment	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Raised to 7.7 then lowered to 4.7	3.14	2.50	36.8	81.1
Control no adjustment 4.7	3.37	3.98	58.5	73.9

Total Water Content (unpressed peat) = 6.81 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 87.2%

a. Each peat sample was approximately 25 g and was pressed at 19.3 atm for 2.5 min.

developed. A high torque stirrer was used to affect mixing. Mixing time and speed were studied to determine what effect these variables might have. At a high mixing speed (300 rpm for 10 minutes) the water content (78.3% Table 5.5) proved to be quite high. However, at a mixing speed of 45 rpm an interesting pattern occurred. A sample of peat which was not mixed contained 74.6% of water after pressing and the water content of the pressed peat declined as the mixing time was increased, reaching a minimum at 5 minutes (Table 5.5.). After a mixing time of 5 minutes, the water content of the peat following pressing increased as mixing time increased, reaching a water content of 76.3% at 60 minutes (Table 5.5.). This pattern can be clearly seen in Figure 5.3., a plot of moisture content of the peat following pressing versus mixing time. The water content of the pressed peat began at approximately 74.5% with no stirring then dramatically dipped to slightly over 73% for a mixing time of five minutes then steadily rose as the stirring time became greater than 5 minutes. Therefore for any peat samples that required the addition of an active reagent, the standard stirring time before pressing was 5 minutes.

Table 5.5. Peat Pressing[a]: Effect of Mixing Time on De-watering (Quebec peat)

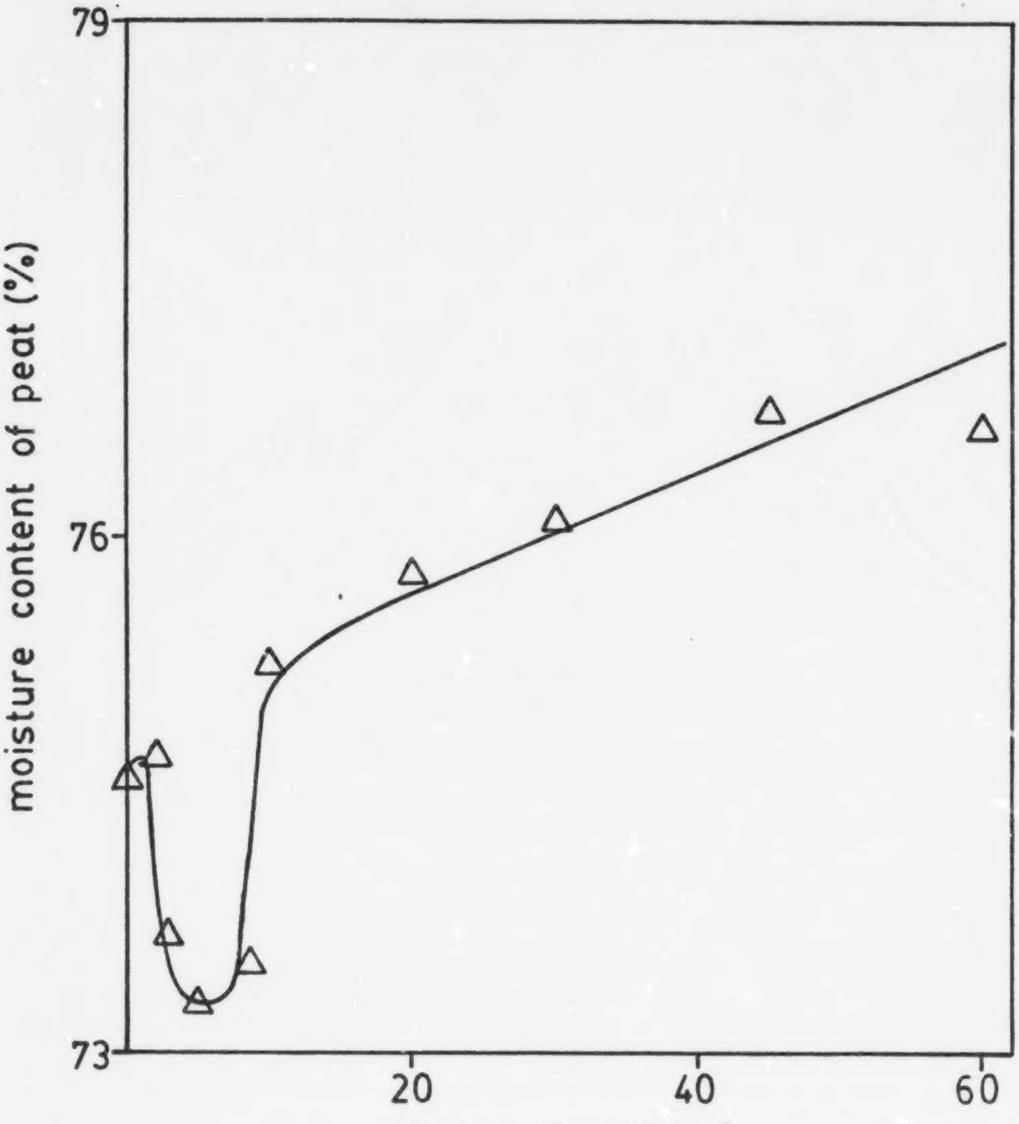
Mixing Time (min)	Mixing Speed (rpm)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0	-	3.12	3.87	57.0	74.6
2	45	2.77	3.86	56.7	74.7
3	45	3.12	4.01	58.9	73.7
5	45	3.15	4.06	59.7	73.3
10	45	3.15	3.76	55.3	75.3
20	45	3.02	3.68	54.1	75.8
30	45	3.30	3.63	53.4	76.1
45	45	3.51	3.57	52.5	76.4
60	45	3.30	3.58	52.6	76.3
10	300	2.93	3.17	46.6	78.3

Total Water Content (unpressed peat) = 6.81 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.2%

a. Each peat sample was approximately 25g and was mixed by means of a high torque stirrer for the specified period of time followed by pressing at 19.3 atm for 2.5 min.

Figure 5.3. Mixing Time Study.

Moisture content of peat versus mixing time



CHAPTER 6

ENHANCED MECHANICAL DE-WATERING OF PEAT USING CHARGED POLYMERS

6. ENHANCED MECHANICAL DE-WATERING OF PEAT USING CHARGED POLYMER

Since peat has colloidal characteristics, the addition of polyelectrolytes (charged polymers) may have a positive effect on the mechanical de-watering of peat. Polyelectrolytes are presently being used in waste-water treatment processes to destabilize colloid formations and it was postulated that they may have a similar effect on peat. Three separate peat samples, a peat sample from Quebec, a Trewartha peat sample (from Northern Ontario) supplied by the Ontario Research Foundation (ORF) and one from Barrington, Nova Scotia, were studied during this investigation.

6.1. CHITOSAN

A biological polymer such as chitosan which can be produced by Rhizopus arrhizus, is a polyelectrolyte. Chitosan contains glucosamine. The nitrogen atom in chitosan is basic in nature and is easily protonated to put a positive charge on the polymer chain (Figure 6.1.). The chloride and bisulfate salts of chitosan were produced, which the chemical elemental analysis verified (Table 6.1), and each was tested for their ability to enhance mechanical de-watering of peat. In a real process the ex-pressed peat water, with the addition of a few nutrients, could then be used to produce the polymer. The growth of the culture on the waste water would solve the water pollution problem since these cultures would use the pollutants in the manufacturing of chitosan and therefore improve the water quality. The initial study, however, used chitosan purchased from the Sigma Chemical Company in order to isolate the salts and ensure that stated concentrations would be accurate.

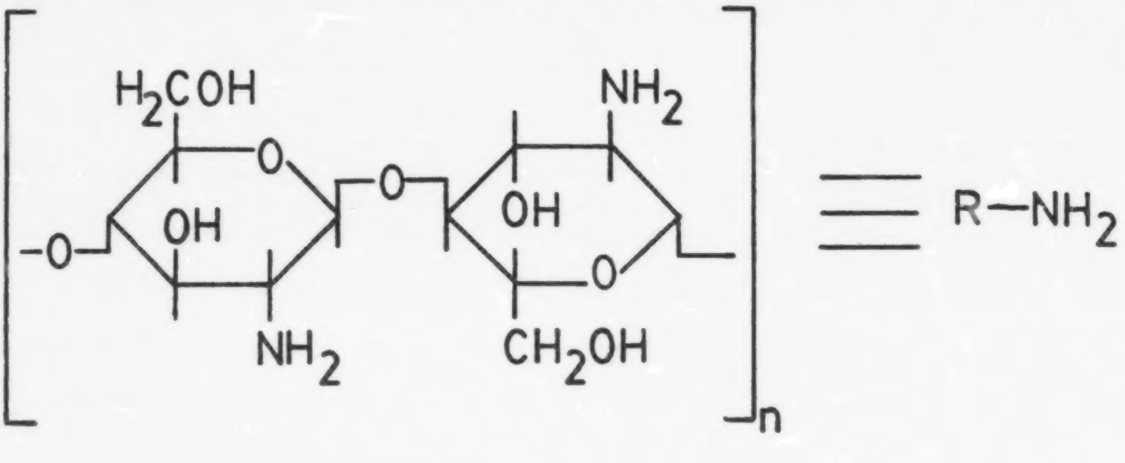
Figure 6.1. The Transformation of Chitosan to a Charged Polymer

$$\mathrm{R{-}NH_2 \;+\; H_2SO_4 \longrightarrow R{-}\overset{+}{N}H_3 \quad H\overset{-}{SO_4}}$$

bisulfate salt
of chitosan

$$\mathrm{R{-}NH_2 \;+\; HCl \longrightarrow R{-}\overset{+}{N}H_3 \quad \overset{-}{Cl}}$$

chloride salt
of chitosan


H₂COH
NH₂
O
O
OH
OH
-O
O
NH₂
CH₂OH
n
≡ R—NH₂

chitosan

Table 6.1. Elemental Analysis of the Chitosan Salts

Element	Chloride Salt		Bisulfate Salt	
	Calculated (%)	Found (%)	Calculated (%)	Found (%)
Carbon	36.47	30.88	27.80	29.32
Hydrogen	6.07	6.07	5.02	6.15
Nitrogen	7.09	4.47	5.40	4.26
Chloride	17.94	9.17	-	-
Sulfur	-	-	12.37	11.30

The effect of chitosan on the Quebec peat is demonstrated in Table 6.2. Mechanical pressing of the peat for 2.5 minutes yielded a control value of 71.8% moisture content which corresponded to a removal of 60.1% of the total water present in the sample. The addition of the bisulfate salt (0.03g per 25g of peat or a ratio of salt to peat of 0.0012) resulted in a modest decrease in the pressed sample's moisture content (69.3% from 71.8%). Increasing the ratio to 0.0024 (0.06g of salt per 25g of peat), the reduction in the water content of the pressed peat was significant (62.7% from 71.8%). From these results it can be seen that this charged polymer aided in peat de-watering.

The chloride salt of chitosan, which has the same cation as the bisulfate salt, was produced in a similar manner. This salt was tested using the same concentrations as the bisulfate salt (0.0012, 0.0024 ratios of salt to peat, Table 6.3.). Each concentration reduced the moisture content to virtually the same level (66.6% and 66.7%). This would indicate that there is an optimum concentration of the active ingredient above which additional polymer has little or no effect. The optimum concentration of the chloride salt (0.0012) was also used with a longer pressing time (4.0 minutes) with the result being a 64.5% moisture content of the pressed peat. It can be seen from Tables 6.2. and 6.3. that a charged derivative of chitosan in conjunction with mechanical pressing removed nearly 70% of the initial water present in the Quebec peat sample.

It should be noted that the two salts of chitosan at similar concentrations (0.0012) give quite different results for de-watering

Table 6.2. Peat Pressing[a]: Using the Bisulfate Salt of Chitosan (Quebec Peat)

Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.0012	3.38	4.14	64.8	69.3
0.0024	3.57	4.71	73.7	62.7
Control	3.31	3.84	60.1	71.8

Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 86.5%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

Table 6.3. Peat Pressing[a]: Use of the Chloride Salt of Chitosan (Quebec Peat)

Ratio of Polymer to Sample (wt./wt.)	Pressing Time (min)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.0024	2.5	3.13	4.40	68.9	66.6
0.0012	2.5	3.23	4.39	68.7	66.7
0.0012	4.0	3.00	4.56	71.4	64.5
Control	2.5	3.31	3.84	60.1	71.8

Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 86.5%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm.

for de-watering (66.7% for the chloride salt, 69.3% for the sulfate salt). This may be entirely due to molecular weight differences. Since 0.03g of each reagent was added to the peat, this means that, because the chloride salt has a lower molecular weight (MW=395) than the bisulfate salt (MW=518), more of the chloride salt was actually added. When the chloride salt was utilized, $8x10^{-5}$ moles of the active reagent was added whereas for the bisulfate salt only $6x10^{-5}$ moles was added. Therefore, more active sites (i.e. more charged species) were present for the chloride salt when equal weights of the two salts were employed.

6.2. SYNTHETIC POLYELECTROLYTES

Commercially available synthetic polymers were tested for their de-watering ability. These polymers consisted of two negatively charged species, Polymer D and Hercofloc 818, one having no charge (non-ionic), Praestol 2810173, and two positively charged species, Praestol 411K and Praestol 444K. Each polymer addition experiment was done in, at least, triplicate with the mixing and mechanical pressing conditions being identical for each sample. The results (Table 6.4.) also include a control in which no polymer has been added but the conditions of pressing are equivalent to those for the polymer-added samples. The comparison of the control with the non-ionic and negatively charged polymer-added samples indicated that these polymers did not enhance de-watering and in fact, they actually retarded water removal. In each case the moisture content of the mechanically pressed peat was only slightly less than the total moisture content (86.5% of the raw peat (Table 6.4.). The positively charged polymers had a far

Table 6.4. Peat Pressing[a]: Using Synthetic Polyelectrolytes (Quebec Peat)

Ionic Type	Ratio of Polymer to Sample (wt/wt)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Polymer D (anionic, low charge)	0.0012	2.44	1.07	16.7	84.3
Hercofloc 818 (anionic, high charge)	0.0012	2.61	0.62	9.70	85.4
Praestol 2810173 (non-ionic)	0.0012	2.98	1.81	28.3	82.1
Praestol 411K (cationic, low charge)	0.0012	2.95	4.46	68.9	65.9
Praestol 444K (cationic, high charge)	0.0012	2.91	4.69	73.4	63.1
Control	-	2.93	3.72	58.2	72.7

Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 86.5%

a. Each peat sample was approximately 25g and the sample was pressed at 19.3 in. atm for 2.5 min.

different effect on the peat pressing. Each polymer (Praestol 411K and Praestol 444K, Table 6.4.) showed a marked improvement in de-watering with the high cationic Preastol 444K having nearly 10% less moisture content than the control. It would appear that charge neutralization played a major role in the enhanced de-watering. That is, the positively charged polymers caused coagulation of the peat particles which allowed more water to be removed by mechanical pressing.

A Trewartha peat sample (supplied by the Ontario Research Foundation) was also studied with Praestol 444K (Table 6.5.). For this sample two pressing times were used to verify that a pressing time of 2.5 minutes was the optimum condition. The pressed control for this peat was lower than for the Quebec peat sample (67.8% compared to 72.7%). This peat had a much lower initial total moisture content, 78.0%, but again the cationic polymer enhanced the mechanical de-watering process. However, an increased pressing time of 4 minutes had little effect on the de-watering since the moisture content was very similar to the 2.5 minute pressings. The study with the three types of synthetic polymers demonstrated that only cationic polyelectrolytes were useful for peat de-watering. This is consistent with the results for the biopolymers tested. Chitosan was an excellent de-watering agent but pullulan and xanthan gum (Table 6.6.) did not work.

Table 6.5. Peat Pressing[a]: Use of Synthetic Polyelectrolyte (Trewartha Peat)

Ionic Type	Ratio of Polymer to Sample (wt./wt.)	Pressing Time (min)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Praestol 444K (cationic, high charge)	0.0012	2.5	6.17	1.87	52.7	62.7
Praestol 444K (cationic, high charge)	0.0012	4.0	6.17	1.83	51.5	63.1
Control	-	2.5	5.52	1.45	40.8	67.8

Total Water Content (unpressed peat) = 3.55 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 78.0%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm.

Table 6.6. Peat Pressing[a]: Use of Polysaccharides (Quebec Peat)

Polysaccharide Added to Peat	Ratio of Polysaccharide to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Arthrobacter viscosus	0.0831[b]	3.96	3.62	56.7	73.4
Aureobasidium pullulans	0.0834[b]	3.76	2.75	43.0	78.4
Xanthan gum	0.002	2.60	0.90	14.1	81.0
Control	-	3.31	3.84	60.1	71.8

Total Water Content (unpressed peat) = 6.39 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 86.5%

a. Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Addition of culture broths.

6.3. POLYELECTROLYTES WITH HIGHLY HUMIFIED PEAT

A second peat sample from Barrington, N.S., was also studied using polyelectrolytes. The Quebec peat sample is a relatively young peat and it would not produce a good fuel grade peat due to its high ash content (Table 6.7.) whereas the Barrington sample is of fuel grade quality. The Barrington peat was difficult to de-water as shown by the control values in Table 6.3. and 6.8. The two synthetic polymers, Praestol 411K and 444K, and the chloride salt of chitosan were all tested with Barrington peat (Table 6.8.). Each enhanced the de-watering process although for the low charge polymer the improvement was only marginal. The chitosan derivative had decreased the moisture content of the pressed peat by almost 8% (70.5% compared to 78.2%, Table 6.8.).

Since the Barrington peat was more difficult to de-water than the Quebec peat, a higher concentration of salt was used in the initial testing (Table 6.8.) in order to ensure maximum de-watering. It was now necessary to determine the optimum concentration of the chloride salt. A concentration of 0.0016 (ratio of 0.04g of salt to 25g of peat, Table 6.9.) proved just as efficient as the higher concentration used initially. This reaffirmed the postulation concerning an optimum concentration as discussed during the Quebec peat testing.

Table 6.7. Analysis[a] of the Barrington N.S., Trewartha and Quebec Peat Samples.

Component Analyzed	Quebec Peat	Trewartha Peat	Barrington Peat
Ash Content (%)	15.3	10.8	11.8
Carbon (%)	48.7	N/A[b]	54.9
Hydrogen (%)	5.0	N/A	5.0
Oxygen (%)	29.1	N/A	25.8
Sulfur (%)	0.21	0.3	0.5
Nitrogen (%)	1.65	N/A	2.0
Initial Moisture Content (%)	86-87	83.5-84	83-85
Degree of Decomposition (von Post Scale)	H6	H8	H9
Caloric Value (MJ/kg) (moisture free base)	N/A	20.7	23.0

a. Analyses performed by the NRC, Atlantic Research Laboratory.

b. N/A: not available

Table 6.8. Peat Pressing[a]: Synthetic Polyelectrolyte versus the Chloride Salt of Chitosan (Barrington, N.S., Peat)

Polymer	Ratio of Polymer to Sample (wt/wt)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Praestol 444K (cationic, high charge)	0.0024	3.40	3.64	59.7	71.1
Praestol 411K (cationic, low charge)	0.0024	2.92	2.88	47.2	76.3
Chloride Salt of Chitosan	0.0024	2.78	3.70	60.7	70.5
Control	-	3.28	2.51	41.1	78.2

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm. for 2.5 min.

Table 6.9. Peat Pressing[a]: Using the Chloride Salt of Chitosan (Barrington, N.S., Peat)

Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.0024	2.78	3.70	60.7	70.5
0.0016	2.96	3.78	62.0	70.0
Control	3.33	2.31	37.9	79.1

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

6.4. PEAT FROM ORF

A third peat sample supplied by the Ontario Research Foundation (ORF) was also investigated using a derivative of chitosan. The control samples (Table 6.10.) showed this peat to be the easiest to mechanically de-water (66.0% moisture content after pressing). Two concentrations (0.0015 and 0.0024, ratio of salt to peat, Table 6.10.) were employed and each decreased the moisture content of the pressed peat as compared to the control. Again there appeared to be an optimum concentration of the salt since the lower concentration (0.0015, Table 6.10.) actually removed 1.5% more water than the higher concentration (0.0024, Table 6.10).

An investigation into multiple pressings was undertaken. Samples were pressed with the chitosan salt and the pressed water was returned to the peat sample with a second addition of the salt and pressed again. The double pressing did remove 2.0% more water (68.5% compared to 70.5%, Table 6.11.) but comparison, of the difference between the doubly pressed sample and its control and the singly pressed sample and its control, showed that the doubly pressed sample removed 6.2% more water (68.5% compared to 74.7%, Table 6.11.) than its control but the singly pressed sample removed 8.6% more water (70.5% compared to 79.1%, Table 6.11.). That is, the second addition of the chitosan salt had no positive effect on de-watering. The increased water removal for the second pressing was solely due to the second mechanical pressing.

Table 6.10. Peat Pressing[a]: Use of the Chloride Salt of Chitosan (ORF Peat Sample)

Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.0024	3.46	3.76	70.8	60.7
0.0015	3.15	3.83	72.3	59.5
Control	3.71	3.36	63.4	66.0

Total Water Content (unpressed peat) = 530 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 84.1%

[a] Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

Table 6.11. Peat Pressing[a]: Multiple Pressings with the Chloride Salt of Chitosan (Barrington, N.S., Peat)

Number of Pressings	Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
2	0.0024 (for each pressing)	2.52	3.93	64.4	68.5
2	Control	2.70	3.15	51.6	74.7
1	0.0024	2.78	3.70	60.7	70.5
1	Control	3.33	2.31	37.9	79.1

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

a. Each peat sample was approximately 25g. The samples were pressed at 19.3 atm for 2.5 min. For the doubly pressed samples, a second addition of the salt was followed again by press[illegible] 19.3 atm for 2.5 min.

6.5. MECHANISM

Only the positively charged polymers caused enhanced de-watering. Polyelectrolytes are often used in water treatment as flocculating agents (see section 3.1.). Much of the peat solid is present as colloidal-size particles. The positively-charged chitosan causes aggregation of these very small particles and improves the separation of the solid phase from the water phase.

This hypothesis is supported by the study with the synthetic polymers which are commercial flocculating agents. The cationic polymers improve de-watering. The anionic and neutral polymers do not help to remove water but cause increased retention. This confirms that the small peat particles have a net negative surface charge.

CHAPTER 7

THE USE OF ENZYMES AND SURFACTANTS TO ENHANCE DE-WATERING

7. THE USE OF ENZYMES AND SURFACTANTS TO ENHANCE DE-WATERING

Enzymes and surfactants, were studied for their ability to aid in peat de-watering. Enzymes produced commercially by Sigma were used. Biosurfactants, were made by various types of bacteria.

7.1. PRESSING STUDIES USING LIPASE

An enzyme requires a certain length of time to act. A long incubation period (17 hr) was used for lipase to ensure maximum activity. The ideal conditions for its use are 37°C and a pH of 7.7. The effect of such a high pH was detrimental, as shown earlier, so a variety of conditions were tested for de-watering (Table 7.1.). De-waterability was increased in all cases but the effect was the greatest at 23°C with no pH adjustment. At the same conditions increasing the amount of lipase added had no beneficial effect. Only a certain amount was necessary to break down the lipids in the peat. Higher concentrations caused water retention, increasing the moisture level of the peat. The higher temperature (37°C) was able to break down some of the colloidal structure of the peat, thereby lowering the control, but addition of lipase did not decrease the moisture content much further (1.3%).

Comparisons between the two types of peat, Barrington and Quebec, were made. The effect of lipase addition was slightly higher for the Barrington. It was 2.6% lower than the control compared to 1.7% in Quebec peat (Table 7.2.). The proportion of lipids holding in the water in the Barrington peat was slightly higher.

Table 7.1. Peat Pressing[a]: Using Lipase (Quebec peat)

Ratio of Enzyme to Sample (wt./wt.)	Conditions	Weight of Peat Sample After Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
0.004	b	3.37	4.55	66.7	69.5
Control	b	3.19	4.40	64.5	70.8
0.004	c	3.37	4.43	65.0	70.5
0.02	c	3.03	5.27	68.1	71.2
Control	c	3.84	4.22	61.9	72.2
0.003	d	3.06	1.97	28.9	82.9
Control	d	3.04	1.34	19.7	84.4
0.004	e	3.30	1.67	24.6	83.5
Control	e	3.46	1.74	25.5	83.6

Total Water Content (unpressed peat)

= 6.82 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 87.2%

a. Each peat sample was approximately 26g and was pressed at 19.3 atm. for 2.5 min.

b. Samples incubated at 37°C for 17 h.

c. Samples incubated at 23°C for 17 h.

d. Samples incubated at 37°C for 17 h and pH raised to 7.5.

e. Samples incubated at 23°C for 17 h and pH raised to 7.5.

Table 7.2. Peat Pressing[a]: Using Lipase[b]

Type of Peat Sample	Ratio of Enzyme to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
Quebec[c]	0.004	3.37	4.43	65.0	70.5
Quebec[c]	Control	3.84	4.22	61.9	72.2
Barrington[d]	0.004	3.39	4.04	58.8	73.9
Barrington[d]	Control	3.09	3.62	52.7	76.5

a. Each peat sample was approximately 25g and pressed at 19.3 atm for 2.5 min.

b. Each sample was incubated at 23°C for 17 h.

c. Total Water Content (unpressed peat) = 6.82 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.2%

d. Total Water Content (unpressed peat) = 6.87 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%

7.2. PRESSING STUDIES USING ESTERASE

Esterase solution was added to Quebec peat and results are shown in Table 7.3. The ideal conditions for incubation are 25°C and pH 8. The temperature was kept constant but the pH was left unadjusted as was done with the lipase. In contrast, de-waterability was greatly improved. The higher concentrations (0.014 and 0.019) lowered the moisture content by more than 7.9% when compared to the control. The amounts of esterase in solution are far too large to be used economically.

When esterase was added to Barrington peat, results were not as good (Table 7.4.) but comparable to lipase activity. Peat of higher decomposition must contain fewer lipids which are responsible for water retention and are not susceptible to esterase treatment.

7.3. MECHANISM FOR DE-WATERING USING ENZYMES

The enzymes studied can cause hydrolysis of waxes and other lipids in the peat. These lipids coat the peat particles and cause surfaces to be hydrophobic. This would trap water in the interstitial spaces. The enzymes, lipase and esterase, break down these components allowing the water to be removed more easily. The composition of the peat waxes determines the ability of the enzymes to aid in the de-watering. The mechanism, though, is not efficient enough to consider a process using only enzymes for pretreatment.

7.4. PRESSING STUDIES USING CELLULASE

Another enzyme cellulase, was added to the peat at three different concentrations. None of these experiments gave positive

Table 7.3. Peat Pressing[a]: Using Esterase[b] (Quebec peat)

Ratio of Enzyme to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
0.004	2.76	5.66	73.2	67.5
0.014	3.64	6.09	78.7	62.3
0.019	2.73	5.99	77.4	63.6
Control	2.70	5.23	67.6	71.5

Concentration of esterase = 10 mg esterase/mL solution

Total Water Content (unpressed peat)

= 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 88.6%

a. Each peat sample was approximately 25g and pressed at 19.3 atm for 2.5 min.

b. Each sample with esterase was incubated at 23°C for 17 h.

Table 7.4. Peat Pressing[a]: Esterase Studies[b]

Type of Peat	Ratio of Enzyme to Sample (wt./wt.)	Weight of Peat Sample After Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
Quebec[c]	0.019	2.73	5.99	77.4	63.6
Quebec[c]	Control	2.70	5.23	67.6	71.5
Barrington[d]	0.019	3.70	4.13	60.1	73.3
Barrington[d]	Control	3.09	3.62	52.7	76.5

a. Each peat sample was approximately 25g and pressed at 19.3 atm for 2.5 min.

b. Each sample was incubated at 23°C for 17 h.

c. Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.6%.

d. Total Water Content (unpressed peat) = 6.87/kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%.

results (Table 7.5.). Cellulase is a major component in peat. Either its degradation does not aid in de-watering or the enzyme is ineffective under the conditions present in the peat.

7.5. PRESSING STUDIES USING SURFACTANT PRODUCED BY B. SUBTILIS

Bacillus subtilis produces a lipopeptide called surfactin, which lowers the surface tension of water from 72 mN/m to 27 mN/m (36). The structure is represented in Figure 7.1. The culture was grown in glucose mineral salts medium for optimum surfactant production and use as a de-watering agent.

Three different forms of surfactin solution were tested (Table 7.6.). In the first case, the entire broth of B. subtilis in glucose medium was used. Compared to the control, the moisture content was lowered by 1.1%, encouraging further study. Next, foam overflow from a fermentation was used. A collection vessel traps the foam coming out the air-exhaust line. The surfactant comes off with the foam, while little remains in the broth. When a sample of foam was added, further de-watering occurred (from 73.7% to 69.7%). The concentration of the surfactant was higher in the foam than in the broth, giving better results.

Lastly, the surfactant was isolated from the foam. This was accomplished easily by removing the cells by centrifugation, adding concentrated hydrochloric acid to the supernatant until a pH of 2 was reached and then removing the precipitate by centrifugation. Distilled water was then added and the pH raised to 7.5 to dissolve the precipitate. The surfactant was concentrated by one-tenth the original amount to ensure maximum de-watering. When the solution was added to the peat, de-watering was even better

Table 7.5. Peat Pressing[a]: Using Cellulase[b] (Quebec Peat)

Ratio of Enzyme to Sample (wt./wt.)	Weight of Peat Sample After Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
0.0014	3.44	5.02	64.9	73.1
0.0018	3.11	5.33	68.9	70.7
0.0048	2.87	5.38	69.5	70.3
Control	2.85	5.33	68.9	70.7

Total Water Content (unpressed peat)

= 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 88.6%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Each sample was incubated at 37°C for 17 h.

Figure 7.1. Structure of Surfactin

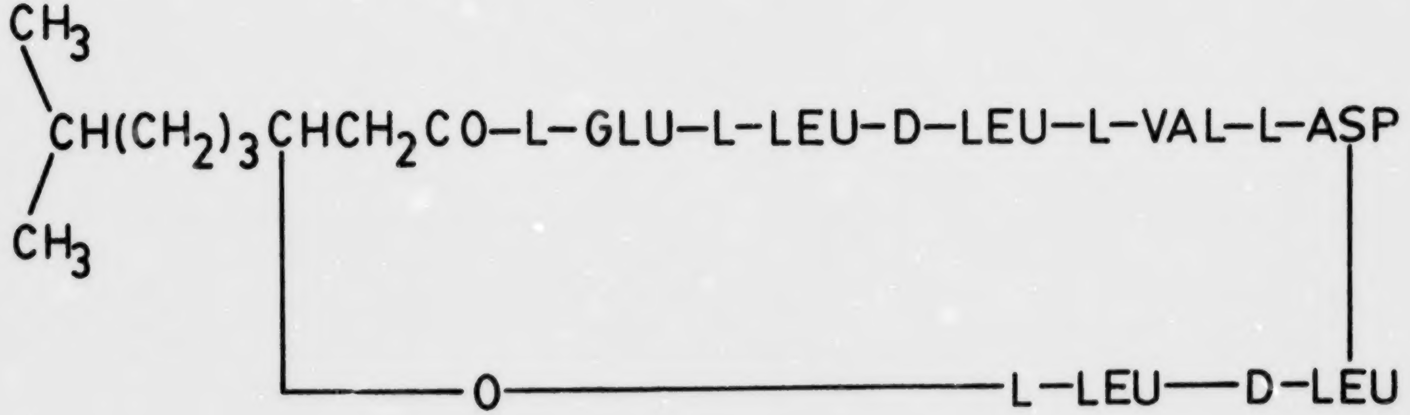

CH3
CH(CH2)3CHCH2CO–L–GLU–L–LEU–D–LEU–L–VAL–L–ASP
CH3
O
L–LEU—D–LEU

Table 7.6. Peat Pressing[a]: Surfactant Produced by B. subtilis (Quebec Peat)

Form of Enzyme to Sample	Ratio of Enzyme to Peat Sample (wt/wt)	Weight of Peat Sample After Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
broth[b]	0.081	3.57	3.82	58.9	70.5
control[b]	-	3.52	3.30	56.7	71.6
foam[c]	0.079	2.71	5.44	70.3	69.7
control[c]	-	2.51	4.93	63.7	73.7
ppt sol'n[c]	0.082	2.62	6.02	77.8	63.2
control[c]	-	3.00	5.04	65.1	73.0

a. Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Total Water Content (unpressed peat) = 5.82 kg H_2O/kg dry peat
% Water Content
(unpressed peat) = 85.6%.

c. Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content
(unpressed peat) = 88.6%.

than the foam by another 6% (Table 7.6.) due to the higher concentration.

Varying amounts of the solution added was investigated (Table 7.7.). Trends were the same in the two peats. The higher concentration of solution (0.096) in the Quebec peat slightly increased the water content of the pressed peat. Similarly, a higher concentration of solution (0.096) lowered the water content of the harder to de-water Barrington peat by 2% less than the lower concentration. More importantly though, it was demonstrated that the precipitate enhanced the ability to remove water in both types of peat.

To ensure that it is the surfactin that is responsible for enhanced de-watering and not the protein which is also present in the precipitate, separation of the two components was done. The precipitate obtained by pH reduction was dried and dichloromethane was added. That which was dissolved in this solvent was surfactin. The protein remained undissolved. The solid was removed by centrifugation and allowed to dry. The solution containing surfactin was left open to the atmosphere to allow the solvent to evaporate completely.

The surfactin and protein were each dissolved separately in distilled water and the pH was adjusted to 7.5. Results are shown in Table 7.8. In both cases, the addition of the protein solutions, caused no significant difference to the control values. In contrast, the surfactin solution lowered the moisture content in the Quebec and the Barrington peats by 4.8% and 1.9%, respectively. The increase in de-waterability is probably not as good as

Table 7.7. Peat Pressing[a]: Using Precipitate of B. subtilis[b]

Type of Peat	Ratio of Solution to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
Quebec[c]	0.082	2.62	6.02	77.8	63.2
Quebec[c]	0.096	3.13	5.96	77.0	64.0
Quebec[c]	Control	3.00	5.04	65.1	73.0
Barrington[d]	0.086	2.95	4.12	60.0	73.3
Barrington[d]	0.096	3.19	3.83	55.7	75.3
Barrington[d]	Control	3.14	2.79	40.6	80.3

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Surfactant ppt. was present in concentrated form in solution at approximately 0.045 g/ml, of which two-thirds is surfactin.

c. Total Water Content (unpressed peat) = 6.82 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.2%.

d. Total Water Content (unpressed peat) = 6.87 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%.

Table 7.8. Peat Pressing[a]: A Study Using a Surfactin and a Protein from the Precipitate of B. subtilis

Type of Agent	Ratio of Agent Sol'n to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)
Protein[b] (Quebec peat)	0.079[d]	2.98	5.52	71.3	69.0
Surfactin[b] (Quebec peat)	0.100[e]	2.70	5.87	75.8	65.2
Control[b] (Quebec peat)	-	3.66	5.50	71.1	69.1
Protein[c] (Barrington peat)	0.079[d]	3.19	3.60	52.4	76.6
Surfactin[c] (Barrington peat)	0.077[e]	3.22	3.81	55.5	75.3
Control[c] (Barrington peat)	-	3.10	3.51	51.1	77.2

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.6%.

c. Total Water Content (unpressed peat) = 6.87 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%.

d. Concentration of protein solution = 0.013 g/mL.

e. Concentration of surfactin solution = 0.018 g/mL.

the precipitate itself due to some degradation during isolation of the compounds. In the Barrington peat, a higher amount of surfactin was needed to obtain the same results as in the Quebec peat.

7.6. CORRELATION OF CONTACT ANGLE AND DE-WATERABILITY

In an attempt to determine why the addition of surfactant is effective in enhanced de-watering, measurement of contact angles was set up. Solutions were measured on wax, extracted by n-butanol from the peat and melted on glass. From interfacial surface tensions and contact angle, the spreading coefficient, S, was determined by the equation:

$$S = \gamma_{SV} - \gamma_{SL} - \gamma_{LV}$$

where γ_{SV} is solid/vapour interfacial tension

γ_{SL} is solid/liquid interfacial tension

and γ_{LV} is liquid/vapour interfacial tension (40).

It is this coefficient that determines the degree of spreading on the waxes. The larger it is, the more easily water flows.

Commercial surfactants at high concentration in distilled water were used as shown in Table 7.9. Concentrations vary because of their solubilities. Use of Span 60, Span 80, Tween 60 and Tween 85 proved very unsuccessful as demonstrated by the increase in water content when compared to the control value. This is not surprising since the spreading coefficient is very high

Table 7.9. Use of Commercial Surfactants as De-watering Agents[a] (Quebec Peat)

Substance Added to Peat	Ratio of Substance to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)	Spreading Coeffi-cient (mN/m)
Span 60 (0.025 g/mL)	0.078	3.02	4.23	54.7	77.8	-35.7
Span 80 (0.015 g/mL)	0.081	3.15	2.27	29.3	85.0	-15.0
Tween 60 (0.012 g/mL)	0.110	3.43	4.38	56.5	77.1	-19.0
Tween 85 (0.012 g/mL)	0.084	2.80	3.30	42.7	81.6	-21.0
Control	-	3.18	4.05	59.4	73.4	-

Total Water Content (unpressed peat)

= 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 88.6%

[a] Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

in all cases. Distilled water with no additives has a spreading coefficient of -24 mN/m as a comparison. The effect of these surfactants does little to aid de-watering and because of the viscosity of the solution, water removal is hindered when pressed. Two surfactant producing cultures, Cornybacterium fascians and

Corynebacterium lepus, were next studied. Both cultures were able to lower surface tension to 29 mN/m when grown in hexadecane and mineral salt media. In each case a sample of the whole broth was used (Table 7.10.). C. fascians did not enhance de-watering when the spreading coefficient was -11.9 mN/m. When it was raised by 5.2 mN/m, moisture content decreased by 4.2%. Although the difference in spreading coefficients was less, C. lepus was also more effective at the higher value of spreading coefficient. Some increase (1.4%) of moisture content occurred because too much broth was added at the higher spreading coefficient. Any broth when added in excess will do this. What is significant is that the same spreading coefficients (S=-6.7 and -6.6 mN/m) given by the different broths, lower the moisture content by about the same amount. Difficulties arose, though, in trying to consistently obtain broths with the same spreading ability. Isolation of the surfactant produced by C. lepus could probably remedy this problem.

Further studies were carried out using the precipitate produced by B. subtilis. The same procedure was used each time to obtain the precipitate. Since the precipitate was not dried when obtained, (drying causes degradation), the specific concentrations could not be determined. Using foams at various times of the

Table 7.10. Use of Surfactant Producing Cultures for Correlation of Contact Angle and Enhanced De-watering[a] (Quebec Peat)

Broth Added to Peat	Ratio of Broth to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)	Spreading Coeffi-cient (mN/m)
Corynebacterium fascians	0.083	2.97	4.06	59.6	73.4	-11.9
C. fascians	0.078	2.98	5.50	71.0	69.2	- 6.7
Corynebacterium lepus	0.093	3.16	3.85	56.5	74.8	- 7.9
C. lepus	0.083	2.90	5.54	71.6	68.7	- 6.6
Control	-	3.18	4.05	59.4	73.4	-

Total Water Content (unpressed peat)

= 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 88.6%

a. Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

fermentation would give varying concentrations of precipitate. Different solutions were then obtained and studied (Table 7.11.). Precipitates #3 and #4 which have low spreading coefficients (-8.9 mN/m) did not aid in de-watering. On the other hand, precipitates #1 and #2 lowered the peat moisture content substantially by 9.8% and 7.1%, respectively. Their spreading coefficients are higher than for the other precipitates and those in Table 7.10.

As a comparison, polypropylene glycol (PPG) which also spreads on wax significantly (S=-4.3 mN/m) was tried. Although the moisture content is approximately the same as precipitate #2, de-watering below the control value is not as good. This could possibly be explained by the fact that PPG is a polymer and changes the properties of the peat differently than the surfactants.

Contact angle measurements were also used for the Barrington peat. Although not many experiments were done (Table 7.12.), it can be seen that higher spreading coefficients lead to better de-watering. Two different precipitate solutions from *B. subtilis* with spreading coefficients of -3.7 mN/m and -5.5 mN/m, lowered the moisture contents by 5% and 3.5%. Comparatively, *C. lepus* spreads less (S=-7.0 mN/m) and gives insignificant de-watering. Also, polypropylene glycol (S=-4.3 mN/m) enhanced de-watering although not as well as precipitate #2.

Plots of this de-watering data are shown in Figures 7.2., 7.3. and 7.4. De-watering ability of surfactant solutions is plotted against surface tension, contact angle and spreading coefficient of the solution. There is no correlation with surface tension

Table 7.11. Correlation of Contact Angle To Enhanced De-watering[a] (Quebec peat)

Solution Added to Sample	Ratio of Solution to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)	Spreading Coeffi-cient (mN/m)
Precipitate #1[b,c]	0.082	2.62	6.02	77.8	63.2	-2.9
Precipitate #2[b,c]	0.089	3.37	5.48	70.1	67.1	-4.4
Precipitate #3[b,c]	0.085	3.58	4.93	63.7	73.4	-8.9
Precipitate #4[b,c]	0.081	3.03	4.87	62.9	74.2	-8.9
Control[c]	-	3.00	5.04	65.1	73.0	-
Polypropylene[d] glycol(neat)	0.002	3.11	4.54	69.4	66.7	-4.3
Control[d]	-	3.14	4.24	64.8	69.7	-

a. Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Same precipitate in each case but different solutions

c. Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.6%

d. Total Water Content (unpressed peat) = 6.54 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 86.8%

Table 7.12. Correlation of Contact Angle With Enhanced De-watering Using Barrington Peat[a]

Type of Agent	Ratio of Agent to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)	Spreading Coeffi-cient (mN/m)
Precipitate #1[b]	0.090	3.19	3.83	55.7	75.3	-3.7
Precipitate #2[b]	0.085	3.33	3.56	51.8	76.8	-5.5
Control[b]	-	3.14	2.79	40.6	80.3	-
C. lepus broth[c]	0.079	3.59	1.80	35.2	76.8	-7.0
Control[c]	-	3.51	1.78	34.8	76.9	-
Polypropylene[d] glycol(neat)	0.002	3.22	4.40	59.0	75.4	-4.3
Control[d]	-	2.77	3.90	52.2	78.1	-

a. Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Total Water Content (unpressed peat) = 6.87 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%

c. Total Water Content (unpressed peat) = 5.12 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 83.7%

d. Total Water Content (unpressed peat) = 7.47 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.2%

Figure 7.2. Study of Surfactants as De-watering Agents. Decrease in moisture Content of peat versus surface tension

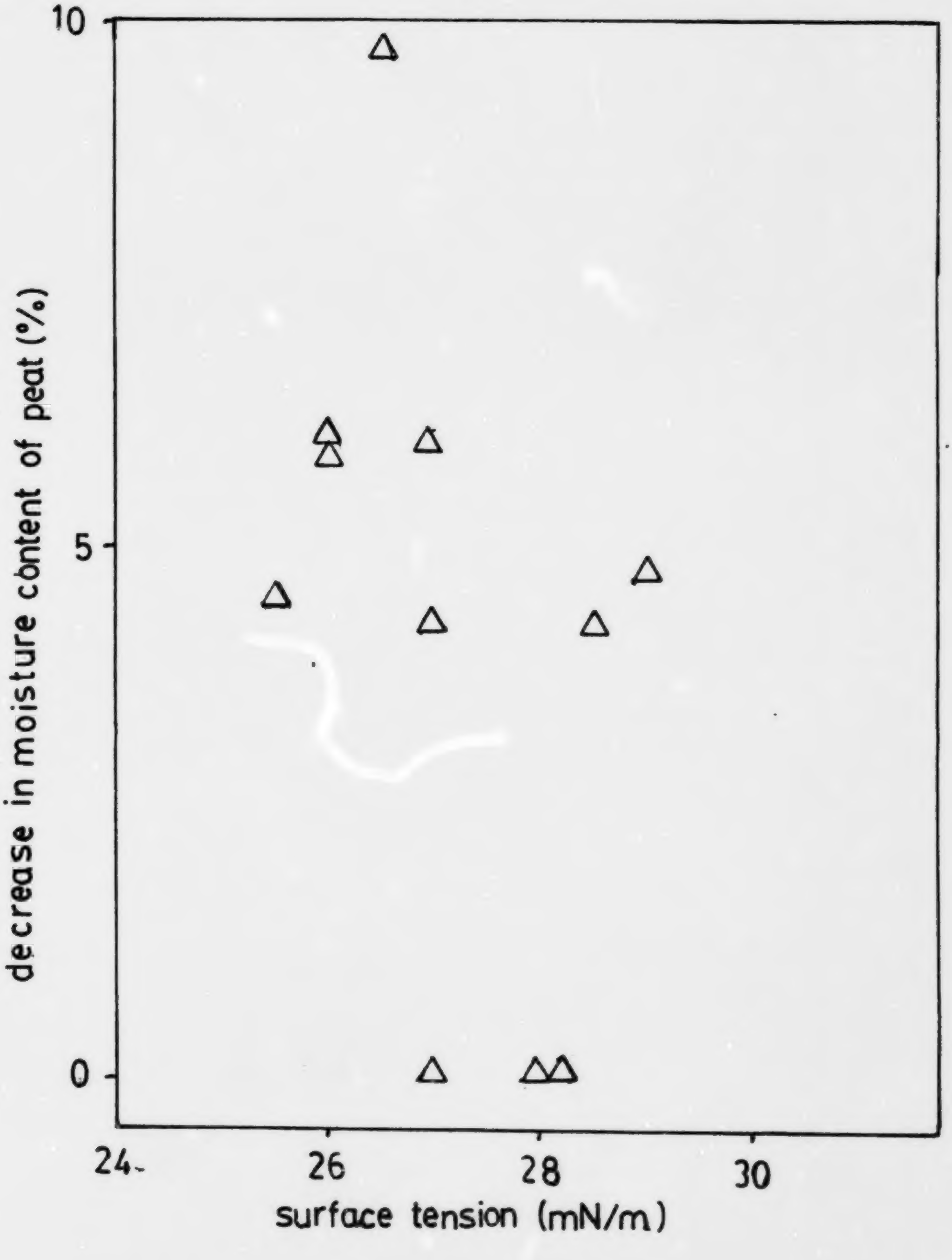


Figure 7.3. Study of Surfactants as De-watering Agents. Decrease in moisture content of peat versus contact angle

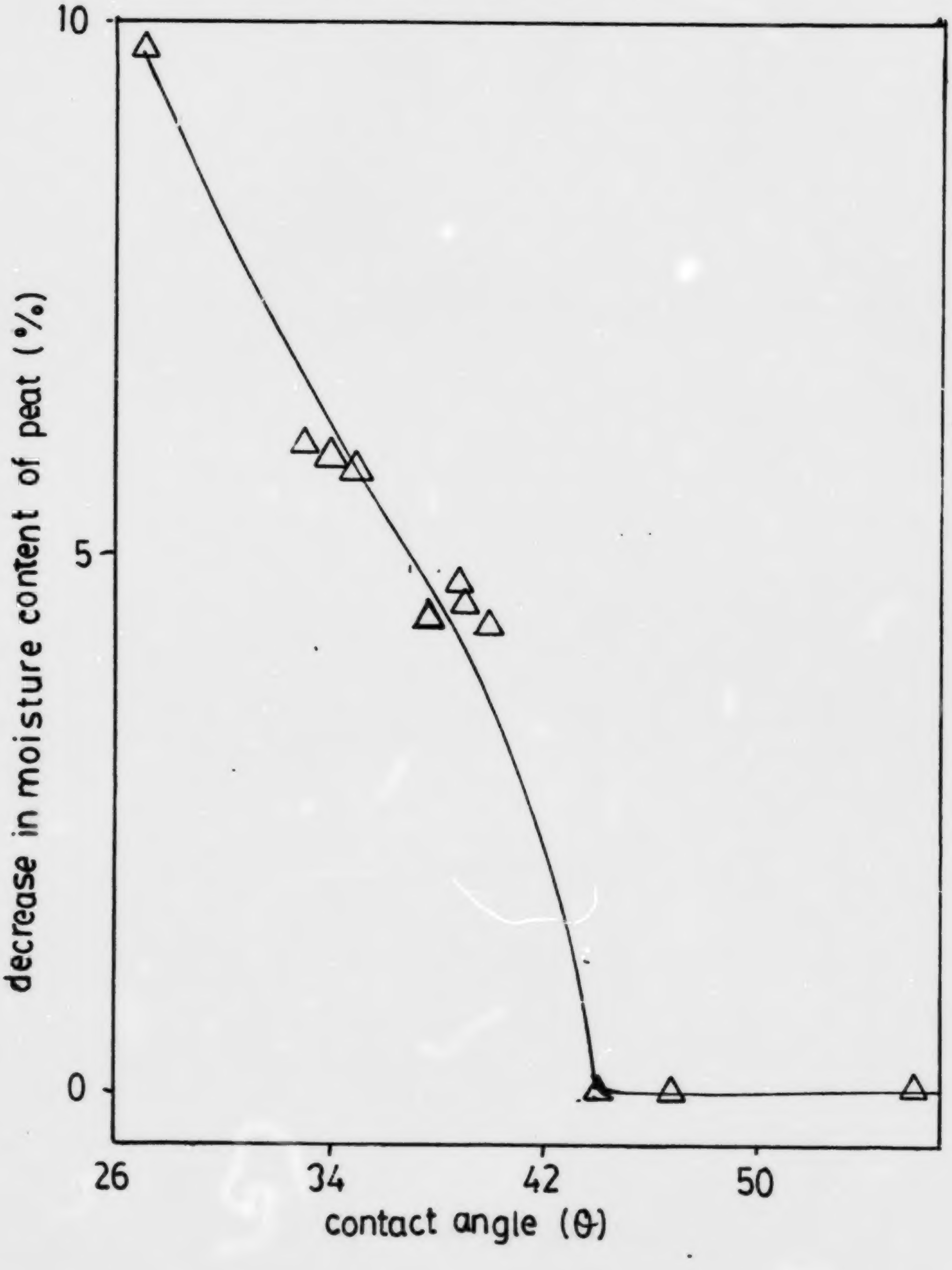
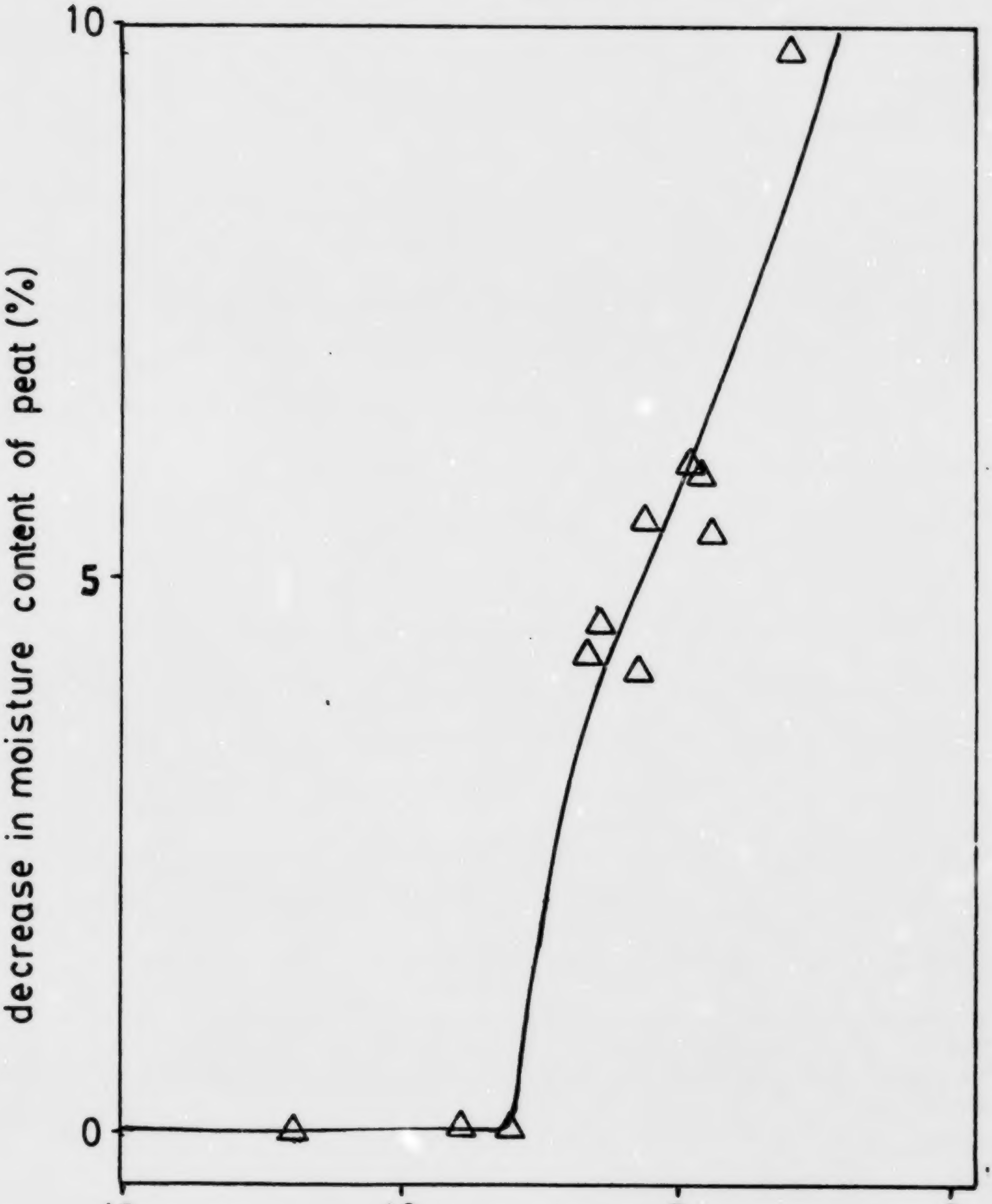


Figure 7.4. Study of Surfactants as De-watering Agents. Decrease in moisture content of peat versus spreading coefficient



except that a very high surface tension means that no surfactant is present. The correlation with contact angle and spreading coefficient is very good. There is a critical contact angle of about 44°. Solutions with larger angles cause no increase in de-watering.

Overall, higher spreading coefficients and lower contact angles seem to mean lower moisture contents. This can again be explained if the hydrophobic lipids coating the particles are causing water to be trapped in interstitial spaces. The enzymes would hydrolyze these materials and remove them from the surfaces, allowing water to move past. The surfactants which cause water to spread on the wax surfaces would decrease the interfacial energy between wax or lipids in the peat and the trapped water and improve de-watering.

7.7. MODE OF APPLICATION OF SURFACTANT

Even though most experiments were done using the concentrated surfactant, it does not have to be used as shown in Table 7.13. Both foam and the precipitate solution from *B. subtilis* provide equally good de-watering in Quebec peat if the concentration of the surfactant in the foam is high. The spreading coefficients are also very close (-4.7 mN/m as compared to -4.5 mN/m). Therefore, contact angle could also be used to determine if the foam is good for enhanced de-watering. Industrially, the use of the foam is more economically feasible since no concentrating of the surfactin will have to be done.

Table 7.13. Correlation of Contact Angle With Enhanced De-watering Using Foam and a Precipitate From B. subtilis[a] (Quebec peat)

Type of Agent	Ratio of Agent to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content Of Pressed Peat (%)	Spreading Coefficient (mN/m)
Foam	0.080	2.66	5.46	71.5	68.4	-4.7
Precipitate	0.081	2.71	5.46	71.5	68.6	-4.5
Control	-	2.62	4.66	61.0	74.4	-

Total Water Content (unpressed peat) = 7.64 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.4%

[a] Each sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

CHAPTER 8

PEAT DE-WATERING USING TWO ACTIVE AGENTS

8. PEAT DE-WATERING USING TWO ACTIVE AGENTS

The success of certain reagents to enhance the de-watering of peat led to the concept of adding more than one of these reagents to the peat to see if these effects could be additive.

8.1 PEAT DE-WATERING USING LIPASE AND OTHER AGENTS

Although lipase had not shown any great ability to enhance de-watering a study was undertaken to determine if, in conjunction with other agents, lipase would have a positive effect on de-watering. The results (Table 8.1.) were obtained with lipase and Praestol 444K (a cationic synthetic polymer) or the bisulfate salt of chitosan. In each case, when lipase was added, there was a slight improvement in the amount of water removed during pressing. The lipase - bisulfate salt combination showed the greatest effect since it removed 3.4% more water than the bisulfate salt only added sample (Table 8.1.). Two other agents, Bacillus subtilis or chloride salt, were also tested with lipase (Table 8.2.) for de-watering enhancement. Neither of these combinations proved successful since in each case, the combination removed less water than the Bacillus subtilis or chloride salt itself.

8.2. PEAT DE-WATERING USING ESTERASE AND OTHER AGENTS

Esterase added to peat samples had shown the ability to remove water during peat pressing (63.6% compared to 71.5% moisture content for a control sample). Again Bacillus subtilis, the chloride salt of chitosan and Praestol 444K were combined with the esterase in a mixed peat pressing study (Tables 8.3. and 8.4.). The results were disappointing since none of the combinations indicated any better de-watering than that which had been obtained

Table 8.1. Peat Pressing[a]: Mixed Study Using Lipase[b] With Other Agents (Quebec Peat)

Agents Added	Ratio of Additives to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Praestol 444K	0.001	2.64	5.84	75.4	65.5
Praestol 444K and Lipase	0.005	3.08	5.95	76.8	64.2
Bisulfate Salt of Chitosan	0.002	2.78	5.66	73.1	67.6
Bisulfate Salt of Chitosan and Lipase	0.005	3.08	5.77	76.8	64.2
Control	-	2.75	4.79	61.9	74.7

Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 88.6%

[a] Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

[b] Each peat sample using lipase was incubated at 23°C for 17 h.

Table 8.2 . Peat Pressing[a] : Mixed Study Using Lipase[b] With Other Agents (Quebec Peat)

Agents Added	Ratio of Additives to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Bacillus subtilis	0.082	2.53	5.98	77.3	63.8
Bacillus subtilis and Lipase	0.081	2.63	5.86	75.2	65.2
Chloride Salt of Chitosan	0.002	3.12	6.16	79.6	61.2
Chloride Salt of Chitosan and Lipase	0.002	2.97	6.15	79.5	61.4
Control	-	2.64	4.79	61.6	74.9

Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 88.6%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

b. Each peat sample using lipase was incubated at 23°C for 17 h.

Table 8.3. Peat Pressing[a]: Mixed Study Using Esterase[b] With Other Agents (Quebec Peat)

Agents Added	Ratio of Additives to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Bacillus subtilis	0.079	2.98	5.53	71.5	68.8
Bacillus subtilis and Esterase	0.073	3.08	5.47	70.8	69.4
Control	-	2.75	4.79	61.9	74.7

Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.6%

a. Each peat sample was approximately 27g and was pressed at 19.3 atm for 2.5 min.

b. Each peat sample containing the esterase solution (10mg/mL) was incubated for 17 h at 23°C.

Table 8.4. Peat Pressing[a]: Mixed Study Using Esterase[b] With Other Agents (Quebec Peat)

Agents Added	Ratio of Additives to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Chloride Salt of Chitosan	0.002	3.12	6.16	79.6	61.2
Chloride Salt of Chitosan and Esterase	0.020	3.04	5.96	77.0	64.0
Praestol 444K	0.002	2.64	5.84	75.4	65.5
Praestol 444K and Esterase	0.020	3.14	5.78	74.7	66.2
Control	-	2.96	4.32	55.8	77.4

Total Water Content (unpressed peat) = 7.74 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 88.6%

a. Each peat sample was approximately 27g and was pressed at 19.3 atm for 2.5 min.

b. Each peat sample containing the esterase solution (10 mg/mL) was incubated for 17 h at 23°C.

by each individual agent. There appeared to be no additive effect of the individual de-watering of these agents.

8.3. PEAT DE-WATERING USING SURFACTIN AND THE CHLORIDE SALT OF CHITOSAN

Surfactin was isolated from *Bacillus subtilis* and was added along with the chloride salt of chitosan to samples of the Quebec peat. The results (Table 8.5.) showed that no enhancement of de-watering was observed, that is, the chloride salt alone de-watered the peat as effectively as the mixture (Table 8.5.).

Table 8.5. Peat Pressing[a]: Mixed Study Using the Chloride Salt of Chitosan and Surfactin (Quebec Peat)

Agents Added	Ratio of Additives to Peat (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed by Pressing (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Chloride Salt of Chitosan	0.0012	2.88	6.20	80.1	60.6
Surfactin	0.0970	3.13	5.96	77.0	64.0
Chloride Salt of Chitosan and Surfactin	0.1092	2.99	6.21	80.2	60.4
Control	-	3.68	5.50	71.1	69.1

Total Water Content (unpressed peat) = 6.87 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 87.3%

a. Each peat sample was approximately 25g and was pressed at 19.3 atm for 2.5 min.

CHAPTER 9

PEAT DE-WATERING USING PREHEAT TREATMENT

9. PEAT DE-WATERING USING PREHEAT TREATMENT

9.1. PREHEAT TREATMENT WITH DERIVATIVES OF CHITOSAN

Another possible method to improve de-watering would be to heat the samples before mechanically pressing. A study of a mild heating process followed the addition of the chitosan salt or other active agent before pressing was initiated. The two synthetic polymers Praestol 411K and 444K were also investigated. Each peat sample was heated for 20 minutes at 125°C followed by the usual addition of charged polymer after which the samples were mechanically pressed. The Barrington peat was employed for this study. The control sample had a moisture content of 69.6% (Table 9.1.) which was significantly better than an unheated control sample for this peat (79.1% moisture content). All three charged polymers when used with preheated samples decreased the moisture content of the pressed peat more than when unheated samples were used (compare the results of Tables 9.1. and 6.8.). However, the chloride salt of chitosan removed 5% more water (61.1% to ~ 66%, Table 9.1.) than either of the synthetic polymers.

Again in this study a high concentration of the active reagent was used to ensure maximum de-watering. The optimum concentration of the chitosan salt was investigated for the heat treated peat samples. Three concentrations, 0.0024 (ratio of 0.06g of salt to 25g of peat), 0.0016 (ratio of 0.04g of salt to 25g of peat) and 0.0008 (ratio of 0.0002g of salt to 25g of peat) were tested (Table 9.2.). The moisture content values for 0.0024 and 0.0016 were very similar (61.1% to 61.7%, Table 9.2.). The lowest concentration of the chitosan salt (0.0008, Table 9.2.) indicated

Table 9.1. Peat Pressing[a]: Synthetic Polyelectrolyte versus the Chloride Salt of Chitosan using Preheated Peat Samples (Barrington, N.S., Peat)

Polymer	Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Praestol 444K (cationic, high charge)	0.0024	2.88	4.16	68.2	66.0
Praestol 411K (cationic, low charge)	0.0024	2.87	4.12	67.5	66.3
Chloride Salt of Chitosan	0.0024	2.71	4.53	74.2	61.1
Control	-	3.37	3.81	62.5	69.6

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

[a] Each peat sample was approximately 25g. The sample was heated at 125°C for 20 min followed by addition of the charged polymer. The sample was pressed at 19.3 atm for 2.5 min.

Table 9.2. Peat Pressing[a]: The Effect of the Concentration of the Chloride Salt of Chitosan on Preheated Peat Samples (Barrington, N.S., Peat)

Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.0024	2.71	4.53	74.2	61.1
0.0016	2.77	4.49	73.6	61.7
0.0008	2.95	4.45	72.9	62.3
Control	3.37	3.81	62.5	69.6

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

a. Each peat sample was approximately 25g. The sample was heated at 125°C for 20 min followed by addition of the charged polymer. The sample was pressed at 19.3 atm for 2.5 min.

that the peat sample had a slightly higher moisture content and therefore the optimum concentration of the chloride salt of chitosan for preheated Barrington peat samples would be 0.0016 (ratio of salt to peat).

There is a dramatic improvement in peat de-watering when both heat and polymer are used over either treatment alone. This was the largest improvement in de-watering observed in our study.

The initial study was done by heating the peat at 125°C. A second heating temperature was also investigated. The procedure was the same as before except the heating temperature was reduced to 109°C. The results, which were obtained using the chloride salt of chitosan, showed that the higher temperature of the heating process removed more water (74.2% compared to 69.6%, Table 9.3.) from the control samples. However the difference between each salt added sample and its control was almost the same (61.1% compared to 69.6% and 66.0% compared to 74.2%, Table 9.3.).

Finally, an investigation into heating time was also performed. The peat samples were heated at 125°C for various lengths of time, 10, 20 and 30 minutes followed by the addition of the polymer and pressing. The results (Table 9.4.) indicated that a 20 minute heating time was superior although the 10 and 30 minute heated samples had only a 2% higher moisture content. Heating time could possibly be reduced if mixing occurred during the heating procedure.

9.2. PREHEAT TREATMENT WITH ENZYMES

In addition to polymers, the use of enzymes, lipase and esterase, with preheat treatment was investigated. (Table 9.5.).

Table 9.3. Peat Pressing[a]: The Effect of Preheating Temperature Using the Chloride Salt of Chitosan (Barrington, N.S., Peat)

Heating Temperature (°C)	Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
125	0.0016	2.71	4.53	74.2	61.1
125	Control	3.37	3.81	62.5	69.6
109	0.0016	2.69	4.16	68.2	66.0
109	Control	2.71	3.22	52.8	74.2

Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat

% Water Content (unpressed peat) = 85.9%

[a] Each peat sample was approximately 25g. The samples were heated at the specified temperatures for 20 min followed by pressing at 19.3 atm for 2.5 min.

Table 9.4. Peat Pressing[a]: The Effect of Heating Time Using the Chloride Salt of Chitosan (Barrington, N.S., Peat)

Heating Time (min)	Ratio of Polymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
10[b]	0.0016	2.77	4.44	72.8	63.6
10[b]	Control	3.04	3.66	60.0	71.0
20[b]	0.0016	2.71	4.53	74.2	61.1
20[b]	Control	3.37	3.81	62.5	69.6
30[c]	0.0016	2.86	3.92	69.5	63.2
30[c]	Control	3.50	3.61	64.0	67.0

a. Each peat sample was approximately 25g. The samples were heated at 125°C for the specified length of time followed by pressing at 19.3 atm for 2.5 min.

b. Total Water Content (unpressed peat) = 6.10 kg H_2O/kg dry peat
% Water Content (unpressed peat) ≈ 85.9%.

c. Total Water Content (unpressed peat) = 5.64 kg H_2O/kg dry peat
% Water Content (unpressed peat) = 84.9%.

Table 9.5. Peat Pressing[a]: Using Enzymes with Preheated Peat Sample (Barrington peat)

Type of Enzyme	Ratio of Enzymer to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Lipase[b]	0.002	3.50	3.16	61.7	66.2
Esterase[b]	0.017	3.65	3.44	67.3	62.6
Control	-	3.34	2.99	58.5	68.8

Total Water Content (unpressed peat)

= 5.12 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 83.7%

a. Each peat sample was approximately 25g. The samples were heated at 125°C for 20 min and pressed at 19.3 atm for 2.5 min.

b. After cooling, lipase or esterase was added to the peat sample. The sample was incubated at 23°C for 1 hour.

Incubation at 23°C for 1 hour was performed after the temperature of the peat had cooled to room temperature and the enzymes were added and mixed in. Hydrolysis of waxes and lipids in the peat is again the main purpose of the enzymes. It was found that esterase was able to lower the moisture content from 68.8% to 62.6% compared to the lipase which only lowered it to 66.2%. This is unlike the occurrance when the enzymes were used with unheated Barrington peat. Both enzymes only lowered the moisture content by about 3% (Tables 7.2. and 7.4.). The heat treatment then must change the composition of the peat waxes which hold in the water, increasing ester content. Incubation time is also substantially reduced.

9.3. PREHEAT TREATMENT WITH SURFACTIN

The surfactant precipitate from B. subtilis was added before and after heat treatment at 125°C for 20 minutes. As when added to unheated peat, this precipitate improved de-watering (Table 9.6.). Adding the precipitate before instead of after heating enabled a longer contact time and thereby lowered the water content by 1.5%. Heat treatment does not degrade the compound. Both samples were mixed after treatment so mixing would have no effect on de-watering. When compared to the unheated Barrington peat, results for the sample added before pretreatment vary a little. In the unheated peat, the precipitate lowered the control from 80.3 to 73.3%. In the heated sample, the moisture content was lowered by 5.2%. The difference could be attributed to different solutions. The spreading coefficient of the solution used in the heat treatment was -4.2 mN/m. Again spreading on peat waxes seems to indicate enhanced de-watering.

Table 9.6. Peat Pressing[a]: Using Surfactin with Preheated Peat Sample (Barrington peat)

Ratio of Solution to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
0.090[b]	3.27	3.22	63.0	65.5
0.096[c]	3.91	3.42	66.8	63.0
-	3.34	2.99	58.5	68.8

Total Water Content (unpressed peat)

= 5.12 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 83.7%

a. Each peat sample was approximately 25g. The samples were heated at 125°C for 20 min and pressed at 19.3 atm for 2.5 min.

b. Surfactin solution added to peat after preheat treatment.

c. Surfactin solution added to peat before heat treatment.

9.4. PREHEAT TREATMENT WITH SURFACTIN AND CHITOSAN SALT TOGETHER

Addition of surfactin and chitosan salt simultaneously was also studied. In all cases, the agents were added and mixed after heating (Table 9.7.). The combination gave significant lowering of water content (6.4% below the control). This value is lower than the surfactin solution but not the chitosan. There is a significant improvement over heating only but the two agents do not compliment each other. This result was similar to the study at ambient temperature.

Table 9.7. Peat Pressing[a]: Mixed Study Using Chloride Salt of Chitosan and Surfactin with Preheated Peat (Barrington peat)

Type of Agent	Ratio of Agent to Sample (wt./wt.)	Weight of Peat Sample after Drying (g)	Amount of Water Removed (kg H_2O/kg dry peat)	Water Removed (%)	Moisture Content of Pressed Peat (%)
Chloride Salt of Chitosan	0.0008	2.75	5.29	77.0	61.2
Surfactin	0.089	3.00	4.96	72.2	65.6
Chloride salt of Chitosan and surfactin	0.0808	3.52	5.41	76.4	61.8
Control	-	3.02	4.71	68.7	68.2

Total Water Content (unpressed peat)

= 6.87 kg H_2O/kg dry peat

% Water Content (unpressed peat)

= 87.3%

[a] Each peat sample was approximately 25g. The sample was heated at 125°C for 20 min followed by the addition of agents. The sample was pressed at 19.3 atm for 2.5 min.

CHAPTER 10

MICROBIAL GROWTH ON PEAT PRESSATES

10. MICROBIAL GROWTH ON PEAT PRESSATES

Attempts to grow various cultures aerobically on peat pressates were made for 2 purposes: to produce substances to enhance de-watering or other uses and to lower the organic content of the water. No results have been reported using peat pressates as substrates, although growth studies have been done on peat extracts (41, 42). It is known that nitrogen and phosphorous are lacking in the peat (43), making their addition necessary. Yeast extract adds various other nutrients to the medium.

10.1. INITIAL GROWTH STUDIES ON PRESSATES

The organisms used in the initial study and their products which include emulsifiers, surfactants and polymers are listed in Table 10.1. These cultures were used to determine if growth was possible. Once growth was established, studies on the microbes' performance were done measuring biomass (Table 10.2.). Peat sediments were removed in all cases throughout unless otherwise specified, as these would be recovered by sedimentation and repressed in a real process. Considering that no optimization was done, growth was significant even though no product was produced in these initial studies.

10.2. GROWTH OF AUREOBASIDIUM PULLULANS

In Table 8.3., results are shown for the growth of Aureobasidium pullulans. Although the polysaccharide was not a de-watering agent, pullulan is a valuable product as a feedstock in the food, drug, petroleum and polymer industries (42). Initial growth in the first medium was substantial, encouraging further

Table 10.1. List of Cultures Used for Initial Study

Culture	Product
Arthrobacter viscosus	viscous polysaccharides
Aureobasidium pullulans	pullulan (44)
Bacillus subtilis	surfactant (lowers surface tension of water from 72 mN/m to 27 mN/m (45)
Isolate from peat	surfactant (lowers surface tension of water to 28 mN/m)
Rhizopus arrhizus	chitosan in cell wall
Torulopsis petrophilum	emulsifier (glycolipid)
Xanthomonas campestris	xanthan gum (46)

Table 10.2. Initial Biomass Studies

Culture	Additives to Peat Water	Biomass (g/L)	Product
Arthrobacter viscosus	0.5% peptone	1.10	none
Isolate from peat	0.4% NH_4NO_3 0.4% KH_2PO_4 0.6% Na_2HPO_4 0.1% yeast extract	0.29	γ^a_{LV} = 50mN/m
	0.4% NH_4NO_3 0.4% KH_2PO_4 0.6% Na_2HPO_4 0.1% peptone 0.1% yeast extract	0.42	γ_{LV}= 58mN/m
Torulopsis petrophilum	0.2% NH_4NO_3 0.1% KH_2PO_4 0.1% yeast extract	0.20	none

a. γ_{LV} - liquid/vapour surface tension

Table 10.3. Growth of Aureobasidium pullulans in Peat Water

	Medium		Biomass (g/L)	Pullulan Produced (g/L)
1)	0.5% K_2HPO_4 0.1% NaCl 0.06% $(NH_4)_2SO_4$ 0.08% yeast extract added to peat water		0.29	none
2)	same mineral salts and yeast extract but 0.08% peptone added to peat water	1st transfer	0.95	none
		2nd transfer	0.85	0.96
		3rd transfer	1.21	1.81
3)	same mineral salts with 0.04% peptone and yeast extract and 2.94 g/ℓ peat in autoclaved peat water		0.6	0.85
4)	same mineral salts and peptone and yeast extract as #2 added to water from autoclaved peat		1.10	very little
5)	40 g/ℓ glucose is used in distilled water and same additives instead of pressate		13.8	10.99

study. The first transfer into medium 2 did not yield pullulan but upon further transfers production did occur. This was most likely due to the fact that the culture was adapting itself to the medium. Growth was much less than in glucose (entry 5) since usable carbon content was much lower. Growth was also attempted in pressate from heat treated peat (125°C for 20 minutes). Inhibition of pullulan production occurred (entry 4) possibly due to some increase of toxic substances. The higher organic content due to the presence of peat particles overcame any increase of toxicity due to heat treatment and led to pullulan production (entry 3). Biomass was reduced because of the lower amounts of peptone and yeast extract added.

10.3. GROWTH OF BACILLUS SUBTILIS

Surfactin producing Bacillus subtilis was studied. The surfactin was shown earlier to be useful as a de-watering agent. Different additives were used with peat pressates (Table 10.4.). In medium 2, surfactant production, which lowers the surface tension to 27 mN/m, was obtained after the second transfer. These results are comparable to those in glucose (entry 4). A control experiment was done by substituting the peat water with distilled water. Biomass was very low, demonstrating that the peptone and yeast extract did not account for much of the growth. Two other media were also utilized.

Although growth was better in medium 5, surfactant production was not good. Medium 6 is a very rich medium which explains the high amount of biomass and surfactant production obtained but its use is not economically feasible.

TABLE 10.4. Studies of *Bacillus subtilis* in Different Media.

	MEDIUM		Biomass (g/L)	Surface Tension (mN/m)
1)	0.4% NH_4NO_3 0.4% KH_2PO_4 0.6% Na_2HPO_4 0.1% peptone in water from peat		0.21	37
2)	0.4% NH_4NO_3 0.4% KH_2PO_4 0.4% Na2HPO4 0.1% peptone 0.1% yeast extract in water from peat	1st transfer	0.29	41
		2nd transfer	0.58	27
3)	medium #2 in distilled water (no peat water)		0.18	33
4)	medium #2 in distilled water with 4% glucose (no peat water)		0.52	27
5)	0.2% $NaNO_3$ 0.1% $K_2H PO_4$ 0.05% KH_2PO_4 0.1% peptone 0.1% yeast extract in peat water		0.67	33
6)	0.5% peptone 0.25% yeast extract in peat water		0.88	27

Attempts were made to lower the amount of peptone and yeast extract required since 0.1% is high in comparison to level of COD in the expressed water (690 mg/L) from both heat treated and nonheat treated peat (Table 10.5.). In the regular peat pressates lowering the concentrations reduced both biomass and surfactant production but growth was still significant when none was added. Therefore, optimization of salts and/or metal concentrations could induce surfactant production. Results were not as good with water from autoclaved peat. Growth is inhibited. Addition of 0.1% peptone and yeast extract is necessary to overcome the lack of growth at lower concentrations. Surfactant production did not occur at all but could possibly be induced at the higher concentrations of peptone and yeast extract.

The effect of addition of peat particles is shown in Table 10.6. In both types of water an increase in biomass occurred due to the presence of nutrients on the particles. In the regular water surfactant production was inhibited by the presence of particles. In the medium with less peptone and yeast extract in the water from autoclaved peat, the additional carbon was needed and used for surfactant production. Only a small difference in surface tension occurred between the two broths with different concentrations of peat, however, as the additional peat could not be used. Higher concentrations of peat particles when autoclaved for sterilization purposes dissolved to a great extent, leaving some toxic and useless substances in the water.

10.4.GROWTH OF RHIZOPUS ARRHIZUS

When it was determined that a chitosan salt was useful in

Table 10.5. Growth of B. subtilis in Different concentrations of Peptone and Yeast Extract in Peat Pressate[a].

Medium (percentage of peptone and yeast extract added)	Biomass (g/L)	Surface Tension (mN/m)
Water from peat		
0.00	0.21	37
0.01	0.27	50
0.10	0.58	27
Water from autoclaved peat		
0.00	0.14	54
0.01	0.10	50
0.10	0.65	33

a. Concentration of mineral salts same as in Table 8.4, medium 2.

Table 10.6. Growth of *B. subtilis* in Peat Pressate With Peat Particles Present[a].

Medium percentage of (peptone and yeast extract added	Concentration of Peat Particles (g/L)	Biomass (g/L)	Surface Tension (mN/m)
Water from peat			
0.1	0.00	0.58	27
0.1	0.21	0.83	37
Water from autoclaved peat			
0.01	0.00	0.10	50
0.01	0.36	0.51	26
0.01	1.99	0.59	30

a. Concentration of mineral salts same as in Table 8.4., medium 2.

aiding de-watering, growth of a fungus which produces this polymer was initiated. Rhizopus arrhizus, contains about 30% chitosan in its cell wall (47). These growth results are shown in Table 10.7. In the pressate from autoclaved peat, growth was possible but slightly less than in the regular peat water because of the lower levels of peptone and yeast extract. Addition of 0.62 g/L of peat particles improved growth somewhat.

10.5.GROWTH OF XANTHOMONAS CAMPESTRIS

The uncharged xanthan gum is produced by Xanthomonas campestris. Various additives to peat water were tried (Table 10.8.). Addition of yeast extract did little to aid growth. In contrast, malt extract increased biomass and xanthan gum was produced. This type of medium is too expensive to be used. In its place, a mineral salts medium with citric acid, peptone and yeast extract was tried (medium 4). Growth as well as xanthan production were good. To ensure that peptone and yeast extract were not present in sufficient quantities to act as substrates, the same components were added to distilled water. These results (entry 5) show that the nutrients in the peat water and not the peptone and yeast extract are being used as the carbon source. To compare growth in a rich medium to medium 4, YM broth was used which consists of glucose, malt extract, yeast extract and peptone in about the same proportions as medium 3. Growth and production are indeed comparable for the amount of carbon present.

In Table 10.9., variations of peptone and yeast extract were made using the two different types of peat pressate. In the first case, increasing peptone influences greatly growth and product

Table 10.7. Growth of *Rhizopus* *arrhizus* in Water Expressed from Peat

Medium	Biomass (g/L)
1) 0.4% NH_4NO_3 0.4% KH_2PO_4 0.4% Na_2HPO_4 0.05% peptone 0.05% yeast extract added to water from peat	0.74
2) same mineral salts and 0.02% peptone and yeast extract added to water from autoclaved peat	0.53
3) medium #2 with 0.62 g/ℓ of peat particles	0.70

Table 10.8. Growth of _Xanthomonas_ _campestris_ in Various Media.

	Medium	Biomass (g/L)	Xanthan Gum Produced (g/L)
1)	0.5% peptone in peat water	0.91	none
2)	0.5% peptone and 0.25% yeast extract in peat water	0.88	none
3)	0.5% peptone 0.25% yeast extract 0.3% malt extract in peat water	1.92	0.59
4)	0.5% KH_2PO_4 0.2% $(NH_4)_2SO_4$ 0.2% citric acid 0.1% peptone 0.1% yeast extract in peat water	1.00	1.70
5)	same medium as in #4 except added to distilled water	0.47	0.44
6)	YM broth (Difco)	1.77	9.16

Table 10.9. Growth of _X. campestris_ with Different Concentrations of Peptone and Yeast Extract in Peat Water[a].

Medium (percentage of peptone and yeast extract added)	Biomass (g/L)	Xanthan Gum Produced (g/L)
Water from peat		
0.01	0.46	none
0.05	0.65	0.76
0.10	1.00	1.70
Water from autoclaved peat		
0.00	0.37	0.40
0.01	0.41	0.56
0.10	1.16	2.00

a. Concentration of mineral salts and citric acid same as Table 8.8. medium 5.

yield. Xanthan was not produced until 0.05% of peptone and yeast extract were added and continued to increase at 0.10%. On the other hand, if water from autoclaved peat which has a slightly different composition was used, no peptone and yeast extract was necessary. This type of water seems to be more favourable for growth. As previously shown, though, increasing the concentration increases biomass and product yield.

The presence of peat particles in the water from autoclaved peat was also investigated. Unlike the results for B. subtilis (Table 10.6.), increasing the amount of peat in the water increased yield and growth (Table 10.10.). The higher concentration of nutrients dissolved in the water by autoclaving and the peat particles aid growth of X. campestris.

10.6. GROWTH IN PRESSATE OBTAINED FROM LOW SEVERITY HEAT TREATED PEAT

A sample of pressate from Dr. Chornet, University of Sherbrooke was used to determine the ability of the microorganisms studied to grow on the water from a high temperature process. The heat treatment involves rapid passage of the peat slurry through a heat exchanger, then expansion through a nozzle. This shearing action is used to break down the structure of the peat. Preheating is done at 136°C for 2 minutes and then the actual treatment is at 195°C for 2 minutes. Four cultures were grown (Table 10.11.), using the same additives for each culture as before. Although the organic content of the water was high due to the temperature treatment of the peat, biomass was quite low as was product yield. A. pullulans grew the best but polymer yield

Table 10.10. Growth of *X. campestris* in Water From Autoclaved Peat With Peat Particles[a].

Concentration of Particles	Biomass (g/L)	Xanthan Gum (g/L)
0.00	0.41	0.56
0.36	0.51	1.61
2.94	0.76	2.01

a. Same concentration of mineral salts, citric acid, peptone and yeast extract as Table 8.8., medium 5.

Table 10.11. Microbial Growth in Peat Pressate After Low Severity Heat Treatment (19)

Culture	Additives to Pressate	Biomass (g/L)	Product
A. pullulans	0.5% K_2HPO_4 0.1% NaCl 0.06% $(NH_4)_2SO_4$ 0.04% peptone 0.04% yeast extract	0.65	very little pullulan
B. subtilis	0.4% NH_4NO_3 0.4% KH_2PO_4 0.4% Na_2HPO_4 0.01% peptone 0.01% yeast extract	0.15	$\gamma_{LV}{}^a$ = 33 mN/m
R. arrhizus	0.4% NH_4NO_3 0.4% KH_2PO_4 0.4% Na_2HPO_4 0.01% peptone 0.01% yeast extract	0.43	0.13 g/L chitosan
X. campestris	0.5% KH_2PO_4 0.2% $(NH_4)_2SO_4$ 0.2% citric acid 0.01% peptone 0.01% yeast extract	0.43	0.15 g/L of xanthan gum

a. γ_{LV} - surface tension

seemed to be inhibited. B. subtilis, a very sensitive microbe to different chemicals, grew very poorly and could not lower the surface tension to 27 mN/m. R. arrhizus and X. campestris, more tolerant microorganisms, grew better. The main problem seems to be the toxicity of the effluent from the low severity process because there is no shortage of carbon.

10.7. DETERMINATION OF THE COD OF PRESSATES

To determine the organic content of several types of pressate, the COD was determined (Table 10.12.). When the peat particles were completely removed by centrifugation, there was no difference between the water pressed from heat treated and unheated peat. During the 125°C treatment for 20 minutes, peat particles did not dissolve in the water to any great extent. In contrast, water with peat particles present after autoclaving had a much higher COD than without heat treatment. Initially, the concentration of the peat particles in the heat treated pressate was 2.14 g/L. Lowering the suspended solids by sedimentation to 0.3 g/L decreased the COD to 2130 mg/L. As a comparison, the organic content of Chornet's pressate was much higher as expected due to dissolved solids. As very few peat particles were present (the pressate was filtered with Whatman #1 paper), this COD value can be compared to our water from heat treated peat with no solids which was much lower in COD (690 mg/L).

10.8. DETERMINATION OF SUSPENDED SOLIDS

Another aspect studied for environmental assessment was the amount of suspended solids in the expressed water (Table 10.13.). Different types of broths were added to the peat including A.

Table 10.12. Measurements of COD on Various Peat Pressates (Barrington peat)

Type of Pressate	COD (mg/L)
Regular peat water	690
Water from heat treated peat (125°C for 25 minutes)	690
Peat water with particles of peat (2.94 g/L)	1935
Water from heat treated peat with peat particles (2.14 g/L)	6760
Water from heat treated peat with less suspended particles (0.3 g/L)	2130
Pressate from low severity heat treatment process (195°C for 2 minutes)	2720

Table 10.13. Determination of Peat Particles Present in Expressed Water

Type of Agent Added	Concentration of Peat Particles (g/L)
Quebec peat	
broths #1	0.64
broths #2	0.60
broths #3	0.72
B. subtilis ppt.	0.47
control	1.04
enzymes	0.37
control	0.93
Barrington peat	
B. subtilis ppt.	2.04
chitosan	1.00
control	2.56

viscosus, T. petrophilum and peat isolate for de-watering studies. The pressate then was used for the determination of peat solids. The addition of the broths lowered the concentration of peat particles substantially. Addition of precipitates from B. subtilis lowered the amount even further in both types of peat. Use of enzymes, lipase and esterase, also gave positive results for the Quebec peat. For the Barrington peat, peat solids are increased because of the higher degree of decomposition of the raw peat. Chitosan was also shown to lower the amount of peat particles in the expressed water significantly. In all cases, the addition of the biological products, proteins and polysaccharides seem to coagulate the particles in the peat, allowing fewer to escape through the filter during pressing into the water.

CHAPTER 11

ECONOMIC EVALUATION OF DE-WATERING PROCESSES

11. ECONOMIC EVALUATION OF DE-WATERING PROCESSES

An analysis was performed to determine the economic feasibility of using biochemical pretreatment for de-watering peat. The capacity of the plant would be 270,000 dry tonnes/year of dry peat. The moisture content of the product would be 10% from a 93% water content slurry feed.

Several processes will be considered:

- Pretreatment of peat with chitosan salt (Barrington peat)
- Pretreatment with a synthetic polymer, Praestol 444K (Bayer) (Barrington peat)
- Pretreatment with surfactant produced by *B. subtilis* (Barrington peat)

The amount of water released by pressing based on a year of production is shown for each of these processes in Table 11.1. The pressate obtained after pretreatment with biological products is then used entirely for fermentation proposes. Included also in the same table is the percentage moisture of the peat after pressing. The amount of water removed increases substantially as moisture content of the peat is decreased. To determine the material balances, it has been assumed that there is a 4% loss of peat fines during pressing and a 1% loss during thermal drying (17).

The analysis is divided into 4 parts: cost of the de-watering agent, cost of preheating, cost of pressing and cost of drying.

Table 11.1. Amount of Water Released During Pressing And Moisture Content of Pressed Peat After Pretreatment[a] (270,000 dry tonne peat/yr)

De-watering Process	Weight of Water Removed (tonnes/yr)	Moisture Content of Pressed Peat (%)
Pretreatment with chitosan	3,130,000	70
Pretreatment with Praestol 444K	3,130,000	70
Pretreatment with surfactant from *B. subtilis*	2,948,000	75
Pretreatment with heat and chitosan (Barrington peat)	3,357,000	60
Pretreatment with heat and chitosan (Quebec peat)	3,433,000	55

[a] Original moisture content of peat before de-watering is 93%.

11.1. PRODUCTION OF DE-WATERING AGENTS

The production of de-watering agents involves: growing the microorganism and altering the product obtained. _B. subtilis_, on the other hand, produces during fermentation a surfactant which becomes concentrated in the foam overflow. No further processing is required. The synthetic polymer, Praestol 444K, only needs to be purchased from Bayer.

The medium for each microorganism was considered as the same base cost. Only 0.01% of peptone and yeast extract are used. Costs were based on Sigma Chemical estimates but were reduced to market price by comparing other items to the Chemical Marketing Reporter (48). Bulk prices would still be lower, though. A small amount of molasses was used to increase the biomass of _R. arrhizus_ for higher product yield of chitosan, even though it was not needed initially for growth to occur. This was not necessary for growth in the higher COD pressate from heat treated peat.

For chitosan extraction from the cell wall of the fungus and inducing a positive charge on the polymer, 2 mL of 1N HCl is used. The prices of chemicals were obtained from the Chemical Marketing Reporter (48).

Production rates and requirements are shown in Tables 11.2. to 11.6. for each de-watering agent along with the costs of the raw materials and final costs of the product. Production and use of polymers and chitosan has been optimized. Requirements for each polymer are 0.01g per 25g of peat. All excess is sold. The selling price of the chitosan salt was determined by comparing the selling prices of other flocculating agents. Chitosan was produced

Table 11.2. Production Cost of Chitosan Salt (1983 Canadian dollars) (Barrington Peat)

Item	Units	Amount
Hydrochloric Acid (0.0073 kg/L)	\$/yr	\$2,153,000
Molasses (0.0005 kg/L)	\$/yr	188,000
Peptone (0.0001 kg/L)	\$/yr	2,348,000
Yeast Extract (0.0001 kg/L)	\$/yr	1,761,000
Total Cost of Raw Materials	\$/yr	6,450,000
Total Cost of Production[a]	\$/yr	18,428,000
Amount of Chitosan Produced	tonnes/yr	2,350
Amount of Chitosan Required	tonnes/yr	1,620
Revenue from Excess Sold[b]	\$/yr	7,300,000
Cost of Production After Revenue	\$/yr	11,128,000
Cost of Product/Weight Dry Peat	\$/tonne	41.21

a. Raw materials taken as 35% of total cost.

b. Product can be sold at \$10/kg.

Table 11.3. Cost of Synthetic Polymer Praestol 444K (1983 Cdn. dollars) (Barrington peat)

Amount Required	1620 tonnes/yr
Total Cost	$16,767,000/yr
Cost per Tonne Dry Peat	$62.10/tonne

Table 11.4. Production Cost of Surfactant from *B. subtilis* (Barrington peat)

Item	Units	Amount
Peptone (0.0001 kg/l)	$/yr	2,211,000
Yeast Extract (0.0001 kg/l	$/yr	1,658,000
Total Cost of Raw Materials	$/yr	3,869,000
Total Cost of Production[a]	$/yr	11,054,000
Cost of Product/Weight Dry Peat	$/tonne	40.94

a. Raw materials taken as 35% of total cost.

Table 11.5. Production Cost of Chitosan Derivative Used With Heat Pretreatment (1983 Cdn. dollars) (Barrington peat)

Item	Units	Amount
Hydrochloric Acid (0.0073 kg/l)	$/Yr	2,308,000
Peptone (0.001 kg/l)	$/Yr	2,518,000
Yeast Extract (0.0001 kg/l)	$/Yr	1,888,000
Total Cost of Raw Materials[a]	$/Yr	6,714,000
Total Cost of Product	$/Yr	19,183,000
Amount of Chitosan Produced	tonnes/yr	2,518
Amount of Chitosan Required	tonnes/yr	1,620
Revenue from Excess Sold[b]	$/yr	8,980,000
Cost of Production After Revenue	$/yr	10,203,000
Cost of Product/Weight Dry Peat	$/tonne	37.79

a. Raw materials taken as 35% of total cost.

b. Product can be sold at $10/kg.

Table 11.6. Production Cost of Chitosan Derivative Used With Heat Pretreatment (1983 Cdn. dollars) (Barrington peat)

Item	Units	Amount
Hydrochloric Acid (0.0073 kg/l)	$/Yr	2,308,000
Peptone (0.0001 kg/l)	$/Yr	2,518,000
Yeast Extract (0.0001 kg/l)	$/Yr	1,888,000
Total Cost of Raw Materials[a]	$/Yr	6,714,000
Total Cost of Product	$/Yr	19,183,000
Amount of Chitosan Produced	tonnes/yr	2,518
Amount of Chitosan Required	tonnes/yr	1,620
Revenue from Excess Sold[b]	$/yr	8,980,000
Cost of Production After Revenue	$/yr	10,203,000
Cost of Product/Weight Dry Peat	$/tonne	37.79

a. Raw materials taken as 35% of total cost.

b. Product can be sold at $10/kg.

at a rate of 0.75g/L. Surfactant produced by B. subtilis was only enough for use. In order to determine the total production cost, the main raw materials were taken as 35% of the cost (49). These costs are shown for each de-watering agent.

Chitosan salt was found to be the least expensive of the de-watering agents to produce in the unheated peat water and therefore the cost was evaluated also in the heat treated peat water. Due to the increase in the amount of water removed, more chitosan can be produced, making the process less expensive.

Production of these biological de-watering agents lowers the COD of the pressate, eliminating the need for pollution treatment.

11.2. PRESSING

In all processes, the cost of de-watering with a Larox filter press was assumed the same (Table 11.7.) (17). This type of press, which is different from those described earlier, works automatically in a semi-continuous batch mode and is available in vertical and horizontal configurations. A feed of 6% solids can be accommodated. Little power is used, which accounts for the low cost of operation. Its parts include filter plate frame, cloth drive closing device, cloth tensioning device, and cloth centering device. The unit can be controlled by either a short or extended program.

11.3. DRYING

Flash drying, which has been used reliably for fuel peat drying is evaluated. These driers are manufactured by Outokumpu. Using the data obtained from Monenco (17), alterations were made

Table 11.7. Economic Analysis of Larox Filter Press (1983 Cdn. dollars) (17)

Item	Units	Amount
Capital Investment	$	15,426,000
Annual Capital Charges (CRF=0.159761)	$/Yr	2,465,000
Annual O & M Costs	$/Yr	935,000
Annual Variable Costs	$/Yr	1,350,000
Total Annual Costs	$/Yr	4,750,000
Cost of Pressing/Weight Dry Peat	$/tonne	17.59

Table 11[illegible] Breakdown of Operating and Maintenance Costs for Flash Drying Peat from 75% to 10% M.C.

No.	Item	Basis of Cost	Total Annual Cost
1.	Operating Labour	49 x $35,000/Yr	1,435,000
2.	Administration & Overload	60% of 1	861,000
3.	Supplies	30% of 1	431,000
4.	Maintenance	3% of Total Plant Cost (77.8% of Total Capital Investment)	1,800,000
	Total	$/Yr	$4,527,000

according to the amount of water removed. Moisture contents of 75%, 70%, 60% and 55% must be lowered to 10%.

Assuming that the energy to remove the water (3500 kJ/kg water removed) is constant, costs were extrapolated from data when moisture content is lowered from 50% to 10%.

Capital investment costs were raised exponentially by a factor of 0.65. Annual variable costs were directly proportional to the amount of heat required. Operating and maintenance costs were obtained from the operating labour and capital costs as shown in Table 11.8.

Each set of costs is represented in Tables 11.8. to 11.12. for each of the moisture levels mentioned earlier (Table 11.1.). Drying costs substantially decrease with moisture level.

11.4. ECONOMIC COMPARISON OF THE VARIOUS DE-WATERING PROCESSES

All economic data of the various de-watering processes are presented in Table 11.13. Three columns not discussed earlier are included. The first is the cost of storage. This includes the cost of storing the peat slurry for 30 days and then pumping it to the de-watering plant (17). Another item is effluent treatment. A two-stage anaerobic/aerobic digestion is required for the JP-Energy Process (17) and the methane produced in the first stage is used as fuel for the drying stage. In our processes, the water is aerobically treated by microbial production of agents that can either be sold or used as de-watering aids. The last item is heat pretreatment. For our processes, treatment is for 10 minutes as compared to the J.P.-Energy which uses a treatment of 210°C for 30 minutes.

The most expensive process is the use of the synthetic polymer

Table 11.9. Cost of Thermally Flash Drying Fuel Peat From 75% to 10% M.C.

Item	Units	Amount
Captial Investment	$	$77,240,000
Annual Capital Charges (CRF=0.159761)	$/Yr	12,340,000
Annual O & M Costs	$/Yr	4,527,000
Annual Variable Costs	$/Yr	
Total Annual Costs	$/Yr	25,811,000
Cost of Drying/Weight Dry Peat	$/tonne	95.60

Table 11.10. Cost of Thermally Flash Drying Fuel Peat From 70% to 10% M.C.

Item	Units	Amount
Captial Investment	$	$63,170,000
Annual Capital Charges (CRF=0.159761)	$/Yr	10,090,000
Annual O & M Costs	$/Yr	3,532,000
Annual Variable Costs	$/Yr	6,625,000
Total Annual Costs	$/Yr	20,247,000
Cost of Drying/Weight Dry Peat	$/tonne	75.00

Table 11.11. Cost of Thermally Flash Drying From 60% to 10% M.C.

Item	Units	Amount
Captial Investment	$	$46,060,000
Annual Capital Charges (CRF=0.159761)	$/Yr	7,359,000
Annual O & M Costs	$/Yr	2,671,000
Annual Variable Costs	$/Yr	4,134,000
Total Annual Costs	$/Yr	14,164,000
Cost of Drying/Weight Dry Peat	$/tonne	52.50

Table 11.12. Cost of Thermally Flash Drying Fuel Peat From 55% to 10% M.C.

Item	Units	Amount
Captial Investment	$	$39,700,000
Annual Capital Charges (CRF=0.159761)	$/Yr	6,343,000
Annual O & M Costs	$/Yr	2,124,000
Annual Variable Costs	$/Yr	3,313,000
Total Annual Costs	$/Yr	11,780,000
Cost of Drying/Weight Dry Peat	$/tonne	43.63

Table 11.13. Comparison of Costs of Various De-watering Processes

De-watering Process[a]	Cost of De-watering Step ($/tonne dry peat)						
	Storage	Effluent Treatment	Cost of Agent	Preheating	Pressing	Drying	Total Cost
Pretreatment with Chitosan	1.28	-	41.21	-	17.59	75.00	135.08
Pretreatment with Praestol 444K	1.28	-	62.10	-	17.59	75.00	159.22
Pretreatment with surfactant	1.28	-	40.94	-	17.59	95.60	155.41
Pretreatment with heat and chitosan (Barrington peat)	1.28	-	37.79	23.36[b]	17.59	52.50	132.52
Pretreatment with heat and chitosan (Quebec peat)	1.28	-	37.32	23.36[b]	17.59	43.60	123.18
JP-Energy[c] (optimized) (210°C for 30 minutes)	1.28	15.49	-	49.00	16.73	15.19[d]	97.66

a. All costs are estimated for our de-watering processes with the exception of JP-Energy.

b. Costs are estimated for preheating at 125°C for 10 minutes.

c. Costs for JP-Energy process are based estimates given to Monenco Ontario Ltd. (17).

d. Methane produced during effluent treatment is used as dryer fuel for steam generation. Peat is used in the other drying processes.

Praestol 444K. Addition of surfactant production by B. subtilis is slightly less expensive and the cost could be further reduced by the addition of molasses. This would increase the yield of surfactant, improve de-watering ability to equal that of the polymers and thus reduce drying costs.

Chitosan is the least expensive agent due to its high sale value which cuts costs and its ability to enhance de-watering. Cost analyses were also done with peat pretreatment. Using Barrington peat, costs are $2.56/tonne less than with no heat pretreatment. Since Quebec peat is easier to de-water than the Barrington, costs are further reduced to $123.18/tonne of dry peat.

In comparison, the JP-Energy is lower in cost due to the fact that its entire process has been optimized. Although chitosan production has been optimized to some extent our entire process has not. The ORF-Wetox process (17) costs $199.10/dry tonne of peat for a 24,750 dry tonne/year plant. The peat also has only been dried to 30% moisture compared to our 10%. Even though our plant size is larger, our process is comparable to that of the ORF.

Overall, chitosan is the most economical de-watering agent. It lowers drying costs and its production on pressates eliminates the cost of effluent treatment. Its use is also economically competitive with other de-watering processes.

CHAPTER 12

CONCLUSION

12. CONCLUSION

The study found that charged polymers, surfactants and lipase were all beneficial in enhancing the mechanical de-watering of peat. It also should be noted that in the case of the chitosan salt (a charged polymer), the results indicated that this agent was more effective at removing water from the more humified peat. It appears that each of these agents (charged polymers, surfactants and lipase) remove the water from the peat by different mechanisms.

The negatively charged peat particles are suspended in the water and the physical attraction between the particles and the water makes it very difficult to remove this water by mechanical pressing. By adding a positively charged species such as the chitosan salt, the negatively charged peat particles are coagulated which allows more water to be removed by mechanical pressing.

De-watering by the biosurfactants is related to the spreading of the water droplets on the waxes coating the peat particles. Surfactants with higher spreading coefficients result in lower moisture contents of peat samples after pressing. The interfacial energy between wax or lipids and the trapped water decreases due to the surfactants and this results in the removal of more entrapped water.

Finally, the mechanism for enhanced de-watering using enzymes, such as, lipase, involves the hydrolysis of the waxes coating the peat particles. The enzyme decomposes these waxes by hydrolysis removing them from the peat particle surface and allowing this water to be removed by mechanical pressing.

The water quality of the pressate was superior to heat pretreatment effluents since less solid material was removed with the water. This in turn would mean more solid product, that is more dry peat, since less was removed during mechanical pressing.

Another aspect of this project was the growth of cultures on the peat pressates. This proved successful since Aureobasidium pullulans, Bacillus subtilis, Rhizopus arrhizus, Xanthomonas campestris and others were grown on the peat water with the addition of a small amount of nutrients. Not only did these cultures grow on the pressed water, they also produced products which either can be used in the de-watering process or in the food, drug, petroleum and polymer industries. A culture such as Rhizopus arrhizus produces chitosan an active de-watering agent for the mechanical pressing process.

An economic evaluation study has shown the pretreatment with biological products is economically competitive with other peat drying processes. The study indicated that this process is economically more efficient with less humified peat such as the Quebec peat sample. The most economical de-watering agent studied was the chitosan salt. It lowers drying costs and its production on pressates eliminates the cost of effluent treatment. It must be noted that, although some optimization has been done on the production of chitosan, the entire de-watering process has not been optimized. Optimization of the total process could lower the cost further and, therefore, it would make this process even more attractive economically.

The heat treatment of the peat prior to the addition of the chloride salt of chitosan was also effective in de-watering the peat. This was an additive effect and pretreatment with heat and chitosan caused a much larger water loss than either treatment alone. A heated control sample had a moisture content of about 9% lower than an unheated control sample. When the chitosan was added, the moisture content was reduced another 8%.

Future work must include a set of experiments which will study the effect of the various parameters on the pretreatment. Work will be continued on the room temperature process as well as heat pretreatment at temperatures up to 200°C. The parameters studied will include: length of preheating, quantity and type of biological agent, time of addition of agent, and effect of stirring. The amount of water removed and the quality of this water will be monitored. The quantity of water expressed and the amount of suspended solids in the water will demonstrate the efficiency of the process to produce the required dry peat solids.

The quality of the water includes several measurements. It is important that this water have the ability to support the growth of microbes which produce valuable compounds. Colour, COD and suspended solids will be monitored before and after biological treatment. Toxicity will also be measured. Specific chemicals which are toxic (eg. phenols) or biodegradable (eg. carbohydrates) will also be considered.

The goal will be an optimization of a relatively mild pretreatment process which results in good water release and relatively little pollution. This data will allow a determination of the most economic process by considering heating costs, quality of the expressed water, fermentation costs, amount of carbon recovered in the pressed solids and value of extra biological products.

The data from different peat samples will allow conclusions about the range of application of the microbes to other processes. Implicit in these conclusions will be at least a partial elucidation of the mechanism of de-watering of the peat. This will aid in improving the process.

Most of the work will be done with peat from Barrington, N.S., to facilitate coordination with research of the Peat Program of the N.R.C. in Halifax. Some work will also be done with other peat samples when optimum conditions are determined.

Acknowledgements

The authors are grateful for the technical assistance of Mr. C. Gick and Mr. J. Rizzi and the typing skills of V. Hubbard. We also acknowledge the assistance of the McGill, Chemical Engineering shop under the direction of Mr. A. Krish.

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